Upper Sacramento River Winter Chinook Salmon Carcass Survey 2004 Annual Report

A U.S. Fish & Wildlife Service Report

Annual Report to

California Bay-Delta Authority
Ecosystem Restoration Program
Project # ERP-01-N46

U.S. Fish and Wildlife Service
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Table of Contents

List of Figures

List of Tables and Appendices

Tables

Appendices

Abstract

The U.S. Fish & Wildlife Service conducts a supplementation program for Sacramento River winter Chinook salmon, an endangered species, at the Livingston Stone National Fish Hatchery. Since 1996, the U.S. Fish & Wildlife Service and the California Department of Fish and Game have cooperated on an annual survey of winter Chinook salmon returning to the upper Sacramento River (Upper Sacramento River winter Chinook salmon carcass survey). Provided in this report is a summary of the 2004 upper Sacramento River winter Chinook salmon carcass survey, including: (1) an evaluation of the winter Chinook salmon supplementation program at the Livingston Stone National Fish Hatchery, and (2) a genetic run identification of the spawning population.

An estimated 636 hatchery-origin winter Chinook salmon returned to the upper Sacramento River in 2004. This represents an estimated increase of 539 fish over what would have been produced if the fish used as broodstock in the Livingston Stone National Fish Hatchery supplementation program had been allowed to spawn naturally. Recoveries of hatchery-origin carcasses included many coded-wire tag codes indicating that the returning hatchery-origin winter Chinook salmon descended from different family groups and likely maintained the genetic diversity of the parent stock. Abundance of hatchery-origin female carcasses increased and peaked approximately one week later than natural-origin female carcasses. Adult hatchery-origin males and females and grilse hatchery-origin males were smaller than their natural-origin counterparts. Too few grilse hatchery-origin females were collected for size comparison to grilse natural-origin females. The proportion of hatchery-origin males returning as grilse was greater than natural-origin males but this difference was not observed for females. Considerably more females were recovered overall for both hatchery-origin and natural-origin fish. A statistically greater portion of hatchery-origin fish returned as males compared to natural-origin winter Chinook salmon. Hatchery-origin and natural-origin winter Chinook salmon carcasses were distributed similarly throughout the survey area. Hatchery-origin and natural-origin females appeared to have equal spawning success based on the numbers of pre-spawn mortalities.

Introduction

In 2004, the U.S. Fish & Wildlife Service (Service) and the California Department of Fish and Game (CDFG) conducted a survey of adult winter Chinook salmon *Oncorhynchus tshawytscha* carcasses in the upper Sacramento River. Primary objectives of the upper Sacramento River winter Chinook salmon carcass survey (carcass survey) were to (1) collect information on several important life history attributes of winter Chinook salmon, including: age and gender composition of the spawning population, pre-spawning mortality rate, and temporal and spatial distribution of spawning, (2) collect data useful in evaluating the winter Chinook salmon supplementation program at the Livingston Stone National Fish Hatchery (NFH), and (3) estimate the abundance of winter Chinook salmon returning to the upper Sacramento River. The following report is submitted to satisfy annual requirements of the Service, including objectives one and two. A complimentary report has been prepared by the CDFG to address objectives one and three. Together, these reports satisfy the reporting responsibilities for the fourth year of this project funded by the California Bay-Delta Authority, formerly CalFed.

Background

The Sacramento River supports four distinct "runs" of Chinook salmon: fall, late-fall, spring, and winter. Adult winter Chinook salmon begin their migration in freshwater from November through June in an immature reproductive state. They migrate into the upper reaches of the Sacramento River, hold in cool waters released from Shasta Dam, and spawn from May through August between the city of Red Bluff (river mile [RM] 245) and the Keswick Dam (RM 302), the upper limit of migration. Most winter Chinook salmon spawn at age three, with the remainder spawning at ages two and four (Hallock and Fisher 1985; Fisher 1994). Virtually all of the grilse (age-2) are males, commonly known as "jacks."

Winter Chinook salmon have been listed as endangered under the Endangered Species Act since 1994 (59 Federal Register 440) due to a small abundance of returning adults and a declining population trend (Figure 1). In 1989, the Service began propagating winter Chinook salmon to supplement natural production and to protect against extinction. The winter Chinook supplementation program was initially located at the Coleman NFH on Battle Creek, a tributary of the Sacramento River. In 1998, the program was moved to a new facility at the base of Shasta Dam, Livingston Stone NFH, to improve imprinting and adult returns to the mainstem Sacramento River.

The Sacramento River winter Chinook salmon recovery plan (National Marine Fisheries Service 1997) specified delisting criteria of a mean annual spawning abundance of 10,000 females and a cohort replacement rate greater than one for 13 consecutive years,. The recovery plan also stipulated that a monitoring system, with an estimation error less than 25%, must be in place to estimate abundance of spawning winter Chinook salmon. Beginning in 1996, the Service and CDFG began cooperating on a carcass survey to improve the precision of population estimates of winter Chinook salmon through the use of a mark-recapture estimator.

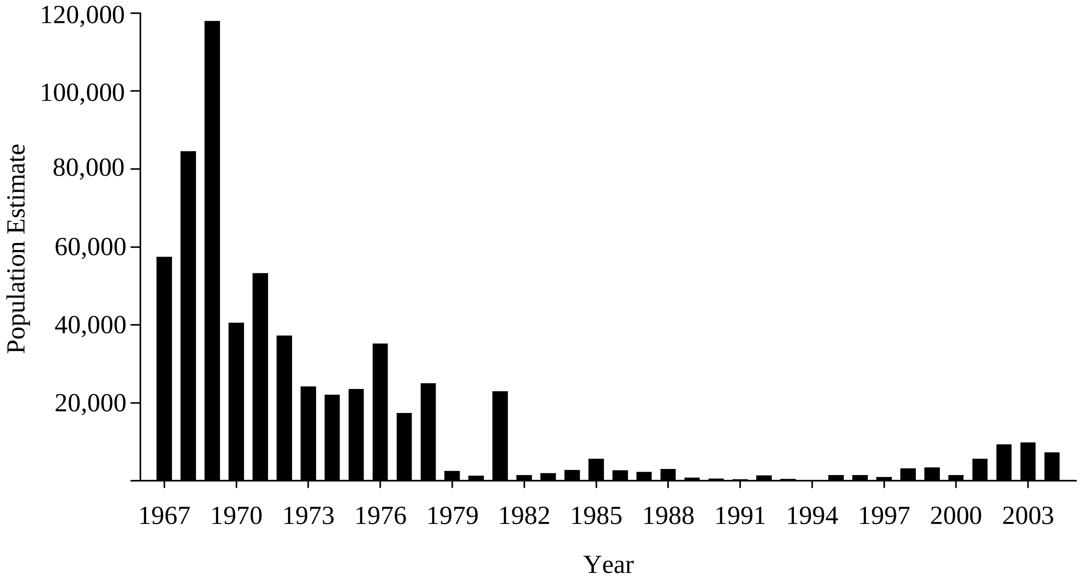

Figure 1. Population abundance estimates for Sacramento River winter Chinook salmon from 1967-2004. Estimates were determined from adult counts made at Red Bluff Diversion Dam, California.

Study Area

The 2004 carcass survey was conducted on the upper Sacramento River, California and was designed to encompass the primary spawning areas of winter Chinook salmon. The survey area covered approximately 29 miles of the Sacramento River and was divided into four reaches (Figure 2): reach 1 extended from the Keswick Dam at river mile (RM) 302 to the Anderson-Cottonwood Irrigation District (ACID) Diversion Dam (RM 298.5); reach 2 extended from the ACID Dam to the Cypress Street Bridge in Redding, California (RM 295); reach 3 extended from the Cypress Street Bridge to Plywood Riffle (RM 287), and reach 4 extended from Plywood Riffle to the mouth of Cottonwood Creek (RM 273.3). In 2004, the survey area was extended further downstream than in recent years.

Figure 2. Upper Sacramento River and the 2004 winter Chinook salmon carcass survey sampling area. Reach 1 extended from the Keswick Dam (RM 302) to the Anderson-Cottonwood Irrigation District (ACID) Diversion Dam (RM 298.5); reach 2 extended from the ACID Dam to the Cypress Street Bridge in Redding, California (RM 295); reach 3 extended from the Cypress Street Bridge to Plywood Riffle (RM 287); and reach 4 extended from Plywood Riffle to the mouth of Cottonwood Creek (RM 273.3). The beginning and ending points of survey reaches may be different between years.

Methods

Carcass Recoveries

The carcass survey was designed to include the entire winter Chinook spawning period and was conducted daily from 30 April 2004 through 3 September 2004 in 3-day cycles. Reaches 1 and 2 were surveyed on the same day, and reaches 3 and 4 each took a day to sample. The order that reaches were sampled in was constant throughout the survey. The survey was conducted with two boats, each having one observer and one operator. The boats surveyed from opposite shorelines to the middle of the river. Carcasses were collected using a 5 meter pole with a five-pronged gig attached. Reach 4 was added in 2004 as a supplemental survey area to determine if a higher proportion of males would be found downstream from the general survey area. Because Reach 4 was not part of the general survey area, effort was not as regular (i.e., the reach was not surveyed every cycle) and this reach was sometimes sampled with only one boat which targeted the primary carcass 'drop out' areas. This reach was surveyed from 10 June 2004 to 3 September 2004.

Data gathered included: date, location (reach, RM, and latitude and longitude), carcass condition (fresh or non-fresh), gender, spawn status (spawned, unspawned, and unknown), fork length (FL), and adipose fin status (absent, present, or unknown). Carcasses were considered to be fresh if they had two clear eyes or one clear eye and firm body texture. Spawn status of females was defined as *spawned* (abdomen extremely flaccid or very few eggs remaining), *unspawned* (abdomen firm and swollen or many eggs remained), or *unknown* (indeterminable spawn status, usually due to predation on the carcass). The spawn status of males was always categorized as unknown. Adipose fin status was used to determine origin: natural-origin or hatchery-origin. An intact adipose fin was assumed to indicate natural-origin and a carcass missing an adipose fin was assumed to be of hatchery-origin. The head was collected from all hatchery-origin carcasses for coded-wire tag extraction in the laboratory. In addition, the head from carcasses with an adipose fin status of "unknown" was collected for examination for a coded-wire tag. These carcasses were later tallied as hatchery-origin if they contained a coded-wire tag or as natural-origin if they did not.

To evaluate the winter Chinook supplementation program at Livingston Stone NFH, hatchery-origin and natural-origin fish were compared to determine the extent to which the following metrics were similar: spatial distribution, spawn timing, gender composition, spawn status, fish length (FL), and age composition. Fork length of hatchery-origin fish was determined from fresh carcasses containing a coded-wire tag. Age composition of hatchery-origin fish was determined from all carcasses containing a coded-wire tag. Analyses of spatial distribution, spawn timing, gender composition, and spawn status of hatchery-origin fish included data from fresh carcasses with a clipped adipose fin and those with an "unknown" adipose fin clip that contained a coded-wire tag. For natural-origin fish, all analyses were conducted with data collected from fresh carcasses without an adipose fin clip and those with an "unknown" adipose fin clip that did not contain a coded-wire tag.

- Spatial Distribution of hatchery-origin and natural-origin winter Chinook was evaluated considering female carcasses only. The frequency of carcass recoveries was plotted against river mile. Frequency distributions were visually compared and examined for substantial differences. The proportion of hatchery-origin and natural-origin fish above and below the ACID Dam was compared using Yates' corrected Chi-square analysis.

- Spawn Timing was evaluated by comparing temporal distributions of female carcass recoveries (natural- and hatchery-origin). The frequency of carcass recoveries was plotted against date and visually compared and examined for substantive differences.

- Gender Composition of hatchery-origin and natural-origin winter Chinook salmon was compared using Yates' corrected Chi-square analysis.

- Spawn status of female hatchery-origin and natural-origin winter Chinook was compared using Yates' corrected Chi-square analysis.

- Length of hatchery-origin and natural-origin carcasses was compared using a separate variance t-test on fork lengths (mm) of carcasses recovered, grouped by gender and age.

- Age Composition of hatchery-origin winter Chinook salmon was evaluated using brood year information obtained from coded-wire tag data. Age composition of natural-origin winter Chinook salmon was determined using length frequency histograms. By looking for logical breaks in the frequency distributions, a cutoff value was determined to distinguish between grilse (age-2) and adults (≥ age-3) for both males and females. Age of hatchery-origin and natural-origin winter Chinook salmon was compared using Yates' corrected Chi-square analysis.

Genetic Analyses

In addition to the above analyses, a tissue sample was collected from the fin or operculum of carcasses that were not extremely decayed for later genetic analysis. When a large number of carcasses were present, tissue samples were collected from a subsample of the carcasses collected (e.g. one out of every three suitable carcasses); otherwise a tissue sample was taken from all suitable carcasses.

A genetic-based run assignment was used to classify carcasses as either "winter-run" or "non-winter-run" Chinook (University of California – Davis Bodega Marine Laboratory 2001) and to determine gender (Du et al. 1993). Genetic analyses were conducted at the Service's Conservation Genetics Laboratory (CGL) located at the Abernathy Fish Technology Center in Longview, Washington. Genetic analyses were conducted on all samples collected during the early (i.e., April and May) and late (i.e., August and September) segments of the run and a random sub-sample of tissues from the peak spawning period (i.e., June and July). Based on data from previous years, we hypothesized that nearly all Chinook salmon carcasses recovered during the peak winter Chinook spawning period would be identified as winter Chinook whereas non-winter Chinook carcasses were more likely to be recovered during the early and late segments of the run.

The results of the genetic-based run assignment were used to estimate the percentage of natural-origin Chinook salmon carcasses that were winter-run. The estimate was calculated from a summation of monthly estimates of the number of winter-run that was based on the number of natural-origin carcasses recovered in each month, the proportion of carcasses determined to be winter-run, and the proportion of samples analyzed for each month.

Using Qiagen Spin Columns, DNA was extracted following manufacturer protocols for animal tissue. Tissue samples were analyzed at a suite of seven microsatellite markers that were selected for their diagnostic power in distinguishing winter Chinook from other Chinook salmon populations (University of California – Davis Bodega Marine Laboratory 2001). Following the methods described by Banks et al. (1999) and Greig and Banks (1999), extracted samples were amplified at 7 microsatellite loci combined into three multiplexed polymerase chain reactions (PCRs): MSA (Ots9, Ots2), MSB (Ots3M, Ots10, One13), and MSC (Ots104 and Ots107). The PCRs were run on MJ Research thermal cyclers using conditions developed at the University of California – Davis Bodega Marine Laboratory and standardized at the CGL. Amplified samples were run on Applied Biosystem's 3100 Genetic Analyzer and analyzed using the Genotyper® software. Overall genotypes were converted to GENEPOP format and individual population assignments determined with the WHICHRUN program (Banks and Eichert 2000). Samples were run 2 or 3 times to confirm genotypes.

Run assignments (winter-run or non-winter-run) were based on log-of-the-odds (LOD) scores generated using the computer software WHICHRUN. In the past, LOD scores were generated using a likelihood ratio based on the average probability of the critical population (winter-run) over the average probability of all other populations in the baseline (University of California – Davis Bodega Marine Laboratory 2001). Recent analysis has shown that the majority of winter-run samples can be identified with greater power and accuracy using the method currently employed for broodstock determination at Livingston Stone NFH (Figure 3). Here, LOD scores are generated based on a likelihood ratio of average probability of the critical population (winter-run) over the next most likely population from the baseline. Using this new methodology, determinations of winter Chinook salmon were tallied for LOD scores of greater than zero, one, or two.

An additional marker, growth hormone pseudogene (GHpsi), was also included as a gender determinate marker. This marker, originally developed by Du et al. (1993), was optimized at the CGL. For this marker, the presence of a 273 base pair allele was indicative of a male Chinook and its absence indicative of a female. A PCR positive was included in all reactions to prevent a failed PCR from being incorrectly assigned as female.

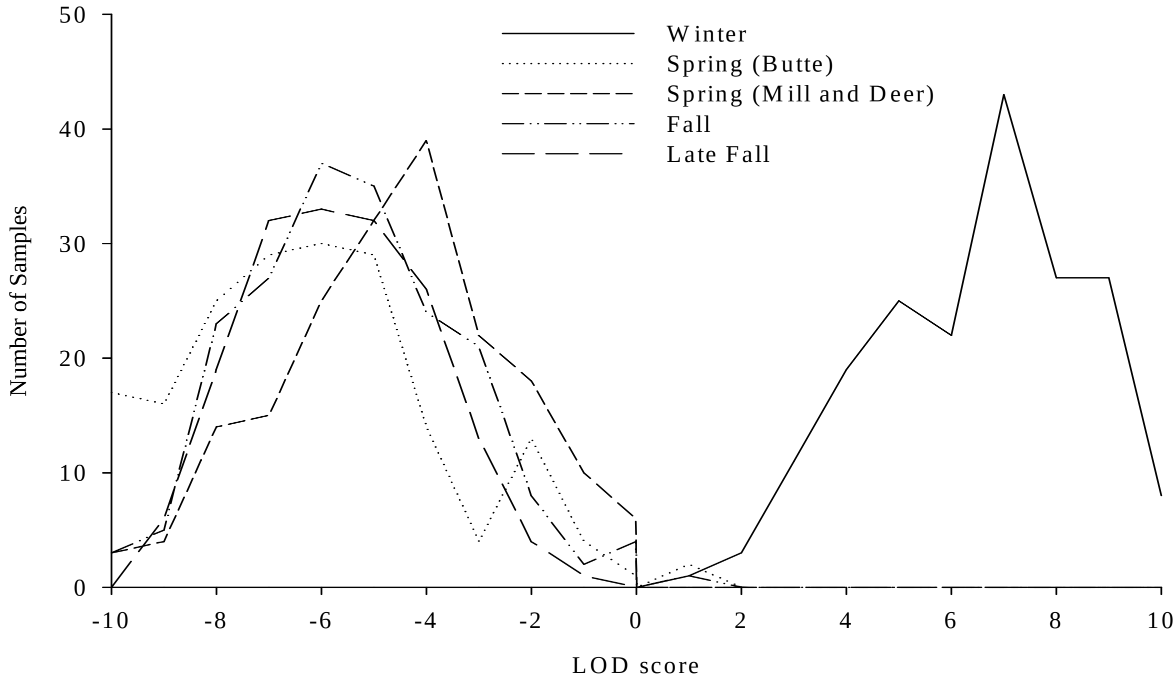

Figure 3. Run assignment of Sacramento River Chinook salmon by log of the odds score (LOD). Run assignments were made based on a $\log_{10}$ likelihood ratio of average probability of the critical population (Winter) over the next most likely population from the baseline.

Demographic Benefit of Hatchery Supplementation

The primary objective of the winter Chinook salmon supplementation program at Livingston Stone NFH is to increase abundance of the naturally spawning population. To evaluate attainment of this objective, we compared the estimated contribution of the hatchery supplementation program to the estimated return had the hatchery broodstock been allowed to spawn naturally.

The winter Chinook salmon escapement that would have been produced by the hatchery broodstock had they been allowed to spawn naturally was estimated based on age composition information for winter Chinook salmon (Hallock and Fisher 1985) and recent winter Chinook salmon population estimates based on the Jolly-Seber mark-recapture method (Appendix A-1; Snider et al., 2000, 2001, and 2002; Killam 2005). Next, we estimated the hatchery-origin winter Chinook salmon escapement due to the existing supplementation program (Appendix A-2). The number of non-fresh hatchery-origin winter Chinook salmon carcasses was expanded based on the proportion of fresh hatchery-origin carcass recoveries among all fresh recoveries. This estimate plus the fresh hatchery-origin carcass recoveries was then expanded to include carcasses believed to have been present, but not observed, during the carcass survey based on the Jolly-Seber mark-recapture method (Killam 2005). Hatchery-origin fish retained at Livingston Stone NFH for use as broodstock were accounted for and the estimate of total clipped hatchery-origin fish was expanded to include hatchery-origin fish that did not receive an adequate fin clip (estimated from mark retention data). The two estimates arrived at from the calculations contained in Appendices A-1 and A-2 above, were then compared to determine the numerical contribution of the hatchery supplementation program to the 2004 winter Chinook run size (Appendix A-3).

Results

Carcass Recoveries

We observed 3,279 carcasses, including 3,029 natural-origin, 229 hatchery-origin, and 21 of unknown-origin. Biological data (i.e., date, location, carcass condition, gender, spawn status, fork length, and adipose fin status) was collected from all hatchery-origin and unknown-origin carcasses and from 1,398 fresh natural-origin carcasses. Six hundred seventeen of the fresh natural-origin carcasses and all of the hatchery-origin and unknown-origin carcasses were tissue sampled.

Coded-Wire Tag Recoveries

We collected heads from 229 hatchery-origin and 21 unknown-origin carcasses. One head was accidentally dropped into the river and never analyzed for a coded-wire tag. Of the remaining heads, we recovered 164 readable coded-wire tags (Appendix B) and 4 unreadable tags (Table 1). One hundred sixty-three of the carcasses with a decoded tag were from brood year 2000, 2001, or 2002 winter Chinook salmon reared at Livingston Stone NFH (Figure 4, Table 2, Appendix C). In addition, one tag (code 050768) was recovered from a brood year 2001 late-fall Chinook salmon reared at the Coleman NFH. Data from this fish was excluded from the remainder of this report.

Thirty-two decoded tags were from progeny of winter Chinook salmon captive broodstock: 19 from brood year 2001 (code 0501030705) and 13 from brood year 2002 (3 of code 051297, 3 of code 051298, and 7 of code 053737). The 21 carcasses originally collected as unknown-origin, based on the adipose fin, were reclassified based on coded-wire tag analysis; 3 as hatchery-origin and 18 as natural-origin. Of the 98 heads collected from non-fresh hatchery-origin carcasses, 69.4% (n = 68) contained a coded-wire tag. For the 128 heads collected from fresh hatchery-origin carcasses, 74.2% (n = 95) contained a coded-wire tag. Among fresh and non-fresh hatchery-origin carcasses, there was no difference in the percent of carcasses containing a coded-wire tag (Yates corrected Chi square: df = 1; P = 0.514). One head was not analyzed for a coded-wire tag and the freshness of one carcass was not determined.

Spatial Distribution

The largest concentration of fresh female hatchery-origin carcasses (32.0%) was found at Turtle Bay (RM 296.5) followed by RM 295 (13.3%) and RM 297 (10.7%) (Figure 5). The largest concentration of fresh female natural-origin carcasses (32.9%) was also found at Turtle Bay (RM 296.5) but followed by RM 297 (14.4%) and RM 295 (14.0%). The proportion of carcasses above the ACID dam (RM 298.5) was similar for hatchery-origin (22.6%) and natural-origin (14.9%) carcasses (Yates corrected Chi square: df = 1; P = 0.102).

Overall, a greater proportion of males (8.6%) were collected in reach 4 than females (0.7%; Yates corrected Chi square: df = 1; $P < 0.001$). This disparity was present among natural-origin carcasses (Yates corrected Chi square: df = 1; $P < 0.001$), but not hatchery-origin carcasses (Yates corrected Chi square: df = 1; $P < 0.130$).

Table 1. Number of coded-wire tag (CWT) recoveries, samples with no tag detected (NTD), and tags with an unreadable code (Unreadable) found during processing of winter Chinook salmon heads collected during the 2004 upper Sacramento River carcass survey. One head was lost and not analyzed for a coded-wire tag (NA). See text for description of 'Carcass condition' and 'Adipose fin'.

Gender	Carcass condition	Adipose Fin	CWT	NTD	Unreadable	NA	Total
Female	Fresh	Hatchery	52	22	1	0	75
Female	Fresh	Unknown	0	7	0	0	7
Female	Non-fresh	Hatchery	34	19	3	0	56
Female	Non-fresh	Unknown	2	8	0	0	10
Female	Unknown	Hatchery	1	0	0	0	1
Male	Fresh	Hatchery	43	11	0	1	55
Male	Fresh	Unknown	1	2	0	0	3
Male	Non-fresh	Hatchery	31	11	0	0	42
Male	Non-fresh	Unknown	0	1	0	0	1
			164	81	4	1	250

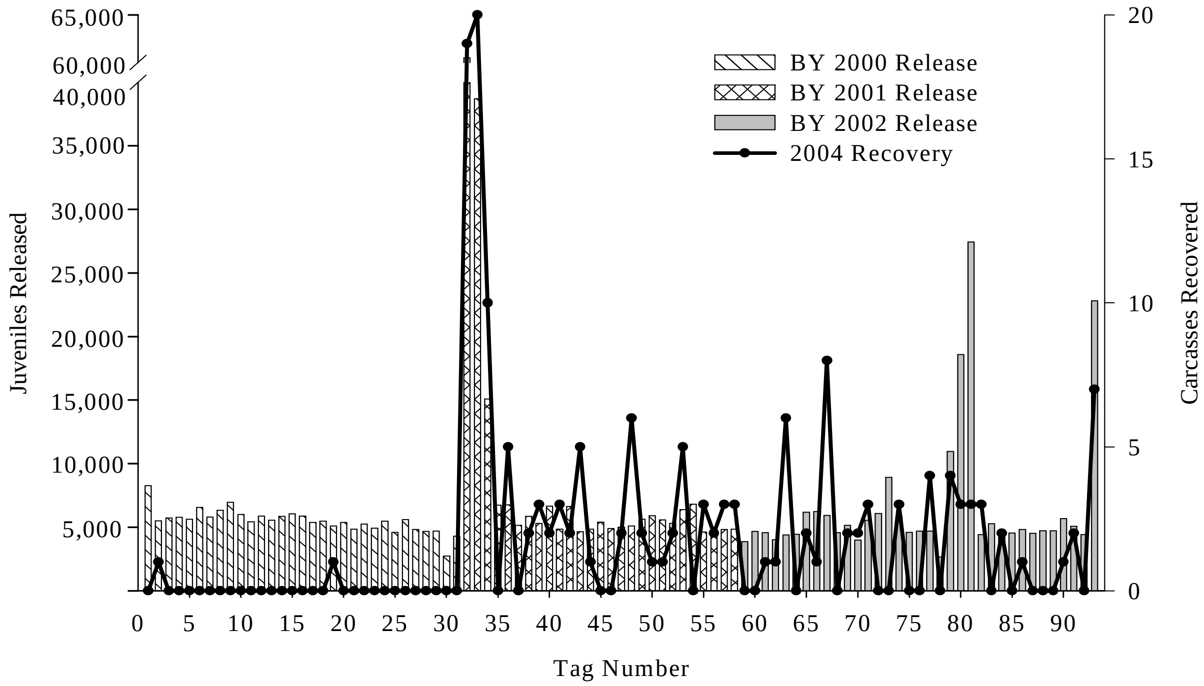

Figure 4. Number of juvenile winter Chinook salmon released and number of carcass recoveries by tag code and brood year (BY) in 2004 (each tag number corresponds to an individual tag code listed in Table 2).

Table 2. Coded-wire tag (CWT) codes inserted into fish released from Livingston Stone National Fish Hatchery during brood years 2000, 2001, and 2002 (tag numbers correspond to those reported in Figure 4). *CWT codes 0501030705, 051297, 051298, and 053737 were used for the progeny of captive broodstock held at the University of California-Davis Bodega Marine Laboratory.

Broodyear 2000		Broodyear 2001		Broodyear 2002	
Tag Number	CWT Code	Tag Number	CWT Code	Tag Number	CWT Code
1	0501030107	31	0501020507	59	051276
2	0501030108	32	0501030705*	60	051277
3	0501030109	33	0501030706	61	051278
4	0501030201	34	0501030707	62	051279
5	0501030202	35	0501030708	63	051280
6	0501030203	36	0501030709	64	051281
7	0501030204	37	0501030801	65	051282
8	0501030205	38	0501030802	66	051283
9	0501030206	39	0501030803	67	051284
10	0501030207	40	0501030804	68	051285
11	0501030208	41	0501030805	69	051286
12	0501030209	42	0501030806	70	051287
13	0501030301	43	0501030807	71	051288
14	0501030302	44	0501030808	72	051289
15	0501030303	45	0501030809	73	051290
16	0501030304	46	0501030901	74	051291
17	0501030305	47	0501030902	75	051292
18	0501030306	48	0501030903	76	051293
19	0501030307	49	0501030904	77	051294
20	0501030308	50	0501030905	78	051295
21	0501030309	51	0501030906	79	051296
22	0501030401	52	0501030907	80	051297*
23	0501030402	53	0501030908	81	051298*
24	0501030403	54	0501030909	82	051299
25	0501030404	55	0501040101	83	051364
26	0501030405	56	0501040102	84	051365
27	0501030406	57	0501040103	85	051366
28	0501030407	58	0501040104	86	051367
29	0501030408			87	051368
30	0501030409			88	051369
				89	051370
				90	051371
				91	051372
				92	051373
				93	053737*

Spawn Timing
Spawn timing, as evidenced by fresh female carcasses (natural-origin and hatchery-origin) recovered throughout the survey period, followed a fairly normal (bell-shaped) temporal distribution (Figure 6). Recovery of natural-origin carcasses peaked in mid-July while recovery of hatchery-origin carcasses peaked approximately one week later.

Gender Composition
Among fresh hatchery-origin carcasses, 42.7% (n = 56) were male and 57.3% (n = 75) were female, whereas fresh natural-origin carcasses consisted of 29.3% (n = 412) male and 70.7% (n = 995) female. The proportion of males to females was greater for hatchery-origin fish than natural-origin fish (Yates' corrected Chi square: df = 1; P = 0.002).

Spawn status
Of the fresh female hatchery-origin carcasses recovered, 71 (94.7%) were classified as spawned and 4 (5.3%) as unspawned. For recovered fresh female natural-origin carcasses, 988 (99.4%) were classified as spawned and 6 (0.6%) as unspawned. The spawn status could not be determined for one natural-origin female carcass. The proportion of spawned and unspawned hatchery-origin and natural-origin females was statistically different (Yates' corrected Chi square: df = 1; P <0.001). Spawn status was not determined for males.

Length
No fresh grilse (Age-2) hatchery-origin females were collected. Adult hatchery-origin females averaged 727 mm fork length (n = 52, range = 590-810 mm, SD = 46.6). Hatchery-origin males averaged 545 mm (n = 35, range = 440-630 mm, SD = 47.4) for grilse and 822 mm (n = 9, range = 710-900 mm, SD = 61.8) for adults (Figure 7).

Using length-frequency analyses, we estimated that natural-origin females ≤580 mm were grilse and ≥ 590 mm were adults. Natural-origin males ≤690 mm were categorized as grilse and ≥700 mm as adults. Natural-origin females averaged 539 mm (n = 10, range = 310-570, SD = 80.8) for grilse and 765 mm (n = 984, range = 590-1120 mm, SD = 51.0) for adults. Length was not measured for one adult female carcass. The fork length of natural-origin males averaged 582 mm (n = 165, range = 430-690 mm, SD = 53.3) for grilse and 903 mm (n = 247, range = 700-1160 mm, SD = 88.6) for adults.

Fork lengths of adult hatchery-origin females and males were significantly smaller than adult natural-origin females (separate variance t-test: df = 57.7; P < 0.001) and males (separate variance t-test: df = 9.2; P = 0.004). No fresh female grilse hatchery-origin carcasses were collected so a comparison between hatchery-origin and natural-origin female grilse was not possible. Grilse hatchery-origin males were significantly smaller than grilse natural-origin males (separate variance t-test: df = 53.8; P < 0.001).

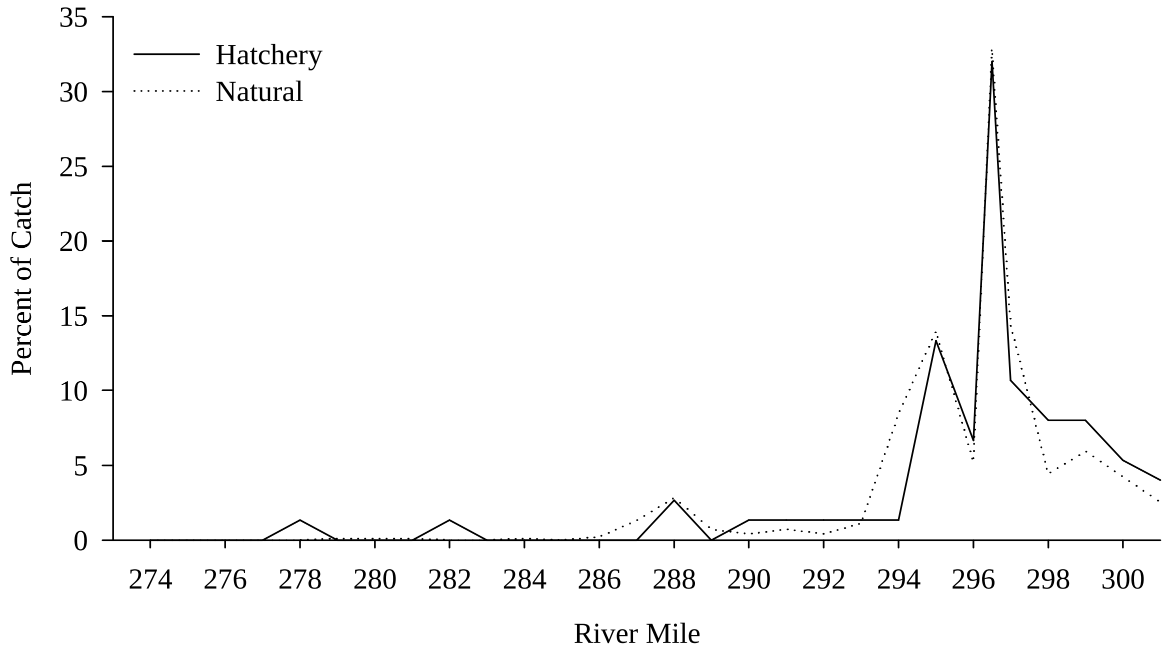

Figure 5. Spatial distribution of fresh female carcasses collected during the 2004 upper Sacramento River winter Chinook salmon carcass survey with an adipose fin clip (Hatchery) and without an adipose fin clip (Natural).

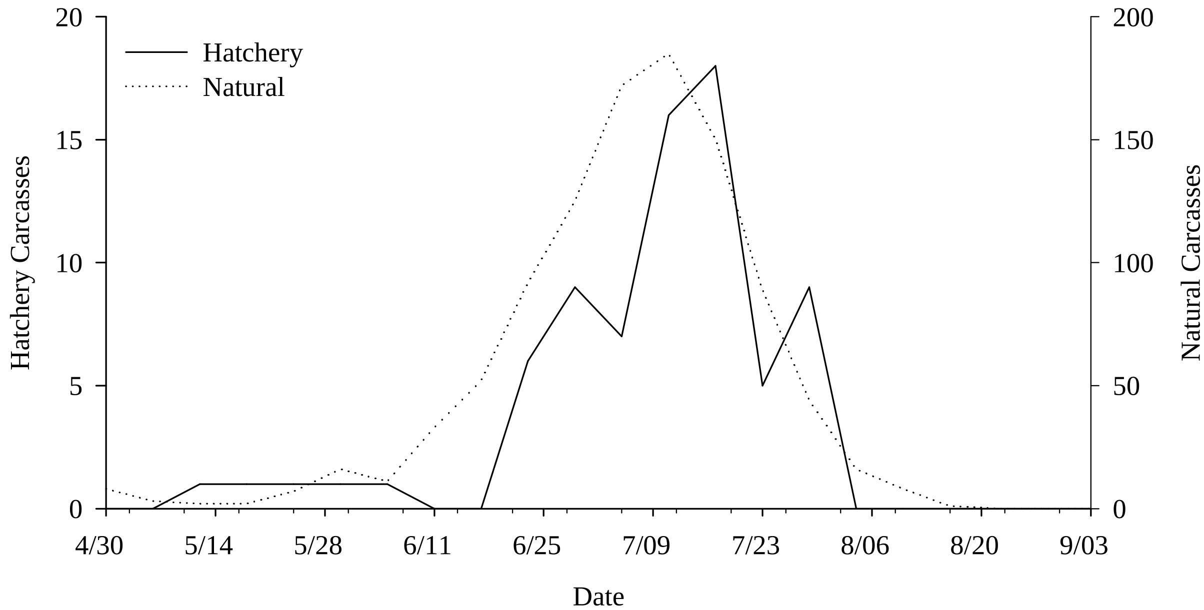

Figure 6. Date of collection of fresh female carcasses recovered during the 2004 upper Sacramento River winter Chinook salmon carcass survey with an adipose fin clip (Hatchery) and without an adipose fin clip (Natural).

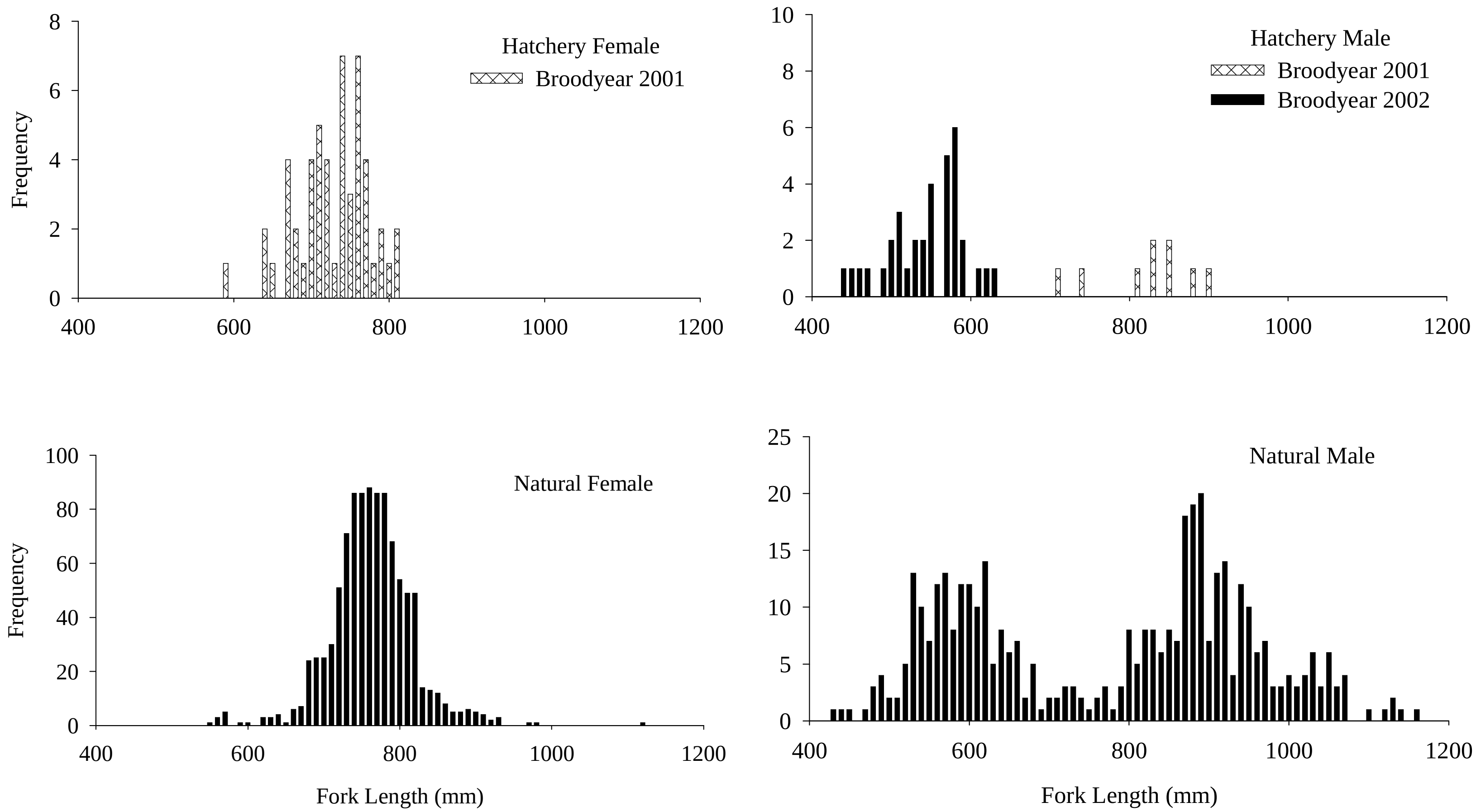

Figure 7. Length-frequency distribution of winter Chinook salmon collected during the 2004 upper Sacramento River winter Chinook salmon carcass survey. Data is presented for males and females with an adipose fin clip (Hatchery Male, Hatchery Female) and without an adipose fin clip (Natural Male, Natural Female). Estimated length of female grilse was < 580 mm fork length. Estimated length of male grilse was < 690 mm fork length.

Age Composition
Hatchery-origin carcasses consisted of 36.0% (n = 59) grilse and 64.0% (n = 105 total; n = 103 age-3 and n = 2 age-4) adult, based on recovered coded-wire tags. Hatchery-origin females consisted of 1.1% (n = 1) grilse (non-fresh carcass) and 98.9% (n = 88 total; n = 86 age-3 and n = 2 age-4) adult, whereas hatchery-origin male carcasses were 77.3% (n = 58) grilse and 22.7% (n = 17; all age-3) adult.

Natural-origin carcasses consisted of 12.4% (n = 175) grilse and 87.6% (n = 1,232) adult, as estimated from length-frequency histograms (Figure 7). Natural-origin female carcasses were 1.0% (n = 10) grilse and 99.0% (n = 984) adult, whereas, natural-origin males consisted of 40.0% (n = 165) grilse and 60.0% (n = 247) adult.

The proportion of hatchery-origin males returning as grilse was significantly greater than natural-origin males (Yates' corrected Chi square: df = 1; $P < 0.001$). The proportion of hatchery-origin females returning as grilse was not significantly different than natural-origin females (Yates' corrected Chi square, df = 1, p = 1.000).

Genetic Analyses
Tissue samples were collected from 661 fresh carcasses (35 hatchery-origin carcasses not identified by the coded-wire tag and 626 natural-origin carcasses). Of these tissue samples, 178 were sent to the CGL with 172 (96.6%) amplifying at the minimum critical loci sufficient to make a run determination (Appendix D). A comparison of the number of samples determined to be winter-run Chinook salmon by LOD score, showed that a score greater than two resulted in 11 fewer fish classified as winter-run relative to when a score greater than zero was applied as in previous years (Table 3). An LOD score greater than one resulted in only three fewer fish classified as winter-run. Samples collected in August accounted for most of the discrepancies in the number of samples determined to be winter-run between the LOD standards. All results in this report are based on LOD scores greater than two.

The small number of samples collected in April and late-August, and the percentage and distribution of samples identified as winter-run during those times, indicated that the 2004 carcass survey adequately sampled the winter-run from a temporal standpoint (Figure 8, Table 3). Of the samples analyzed from carcasses collected in April, only 27% were identified as winter-run and all of those were collected on, or after, April 26th. The last genetically identified winter Chinook salmon was collected on 20 August 2004, after which no carcasses suitable for tissue sampling were collected. Based on an LOD greater than two, 92% of the natural-origin carcasses recovered during May – August 2004 were winter-run Chinook salmon. The percentage of winter-run Chinook carcasses increased to 98% when an LOD greater than zero was applied (as in past years).

Gender was determined genetically for all 178 tissue samples analyzed and then compared to the phenotype observed during the carcass survey, which was assumed to be without error. The gender was correctly determined for 156 (87.6%) samples. Considering only the 172 samples that were genetically identified to run, gender was correctly determined for 153 (89.0%) samples.

Table 3. Comparison of the number of carcasses identified as winter Chinook salmon, by month, using different log-of-the-odds (LOD) scores as a benchmark. A total of 178 samples were genetically analyzed with 6 failing to sufficiently amplify.

	LOD > 0			LOD > 1			LOD > 2		
Month	WCS	Total	%	WCS	Total	%	WCS	Total	%
April	3	11	27.3	3	11	27.3	3	11	27.3
May	30	46	65.2	30	46	65.2	29	46	63.0
June	33	34	97.1	33	34	97.1	30	34	88.2
July	33	34	97.1	32	34	94.1	32	34	94.1
August	46	47	97.9	44	47	93.6	40	47	85.1
Total	145	172	84.3	142	172	82.6	134	172	77.9

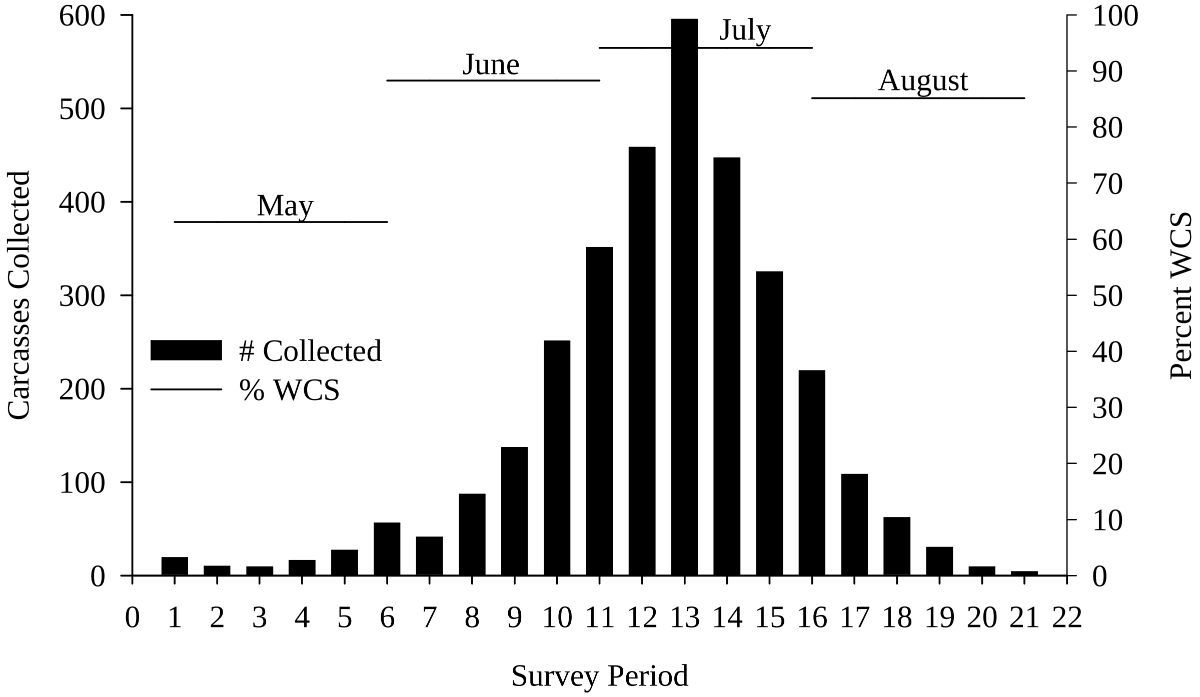

Figure 8. Total number of carcasses collected during the 2004 upper Sacramento River winter Chinook salmon carcass survey and percentage of tissue samples genetically identified (LOD > 2, see text for explanation) as winter Chinook salmon (WCS). The 2004 carcass survey was conducted from 30 April through 3 September 2004. One ‘survey period’ is equal to two surveys of each Reach 1 through Reach 4 (two survey cycles, 6 days).

Demographic Benefit of Hatchery Supplementation

We estimated that 636 hatchery-origin winter Chinook salmon returned in 2004 (Appendices A1-A3). Additionally, we estimated that the Chinook salmon adults used as hatchery broodstock at the Livingston Stone NFH in 2000, 2001, and 2002 would have resulted in 97 adult returns in 2004 had they been allowed to reproduce naturally. The results of our analyses indicate that the Service's winter Chinook salmon supplementation program increased escapement to the upper Sacramento River by 539 fish, or a 557% increase relative to what would have been produced if the broodstock had been allowed to spawn naturally.

Discussion

Carcass Recoveries

The Service's winter Chinook salmon supplementation program was moved from the Coleman NFH to the Livingston Stone NFH in 1998. The primary reason for moving the supplementation program to the Sacramento River main stem was to improve homing of hatchery-origin fish to the mainstem spawning areas used by natural-origin winter Chinook salmon. Most hatchery-origin winter Chinook salmon returned to Battle Creek when the program was located at the Coleman NFH. By incubating eggs and rearing juveniles at Livingston Stone NFH, it was believed that hatchery-origin winter Chinook salmon would be much more likely to return to spawning areas in the Sacramento River. Recoveries of hatchery-origin carcasses during the 2004 carcass survey show that hatchery-origin winter Chinook salmon from Livingston Stone NFH are imprinting and returning to spawning areas in the Sacramento River.

Coded-Wire Tag Recoveries
Hatchery-origin winter Chinook salmon recovered during the 2004 carcass survey were from Livingston Stone NFH brood years 2000, 2001, and 2002. Nearly all of the tag codes released from Livingston Stone NFH for brood year 2001 (age-3) were represented in the carcass recoveries. Each tag code represents an individual family group or a cluster of family groups, where a family group is defined as the progeny of an individual female and male mating. The recovery of many tag codes provides evidence that the genetic diversity of the parental stock was represented in the 2004 returns.

Spatial Distribution
The distribution of salmon carcasses was variable throughout the survey area, with areas of decreased velocity (pools) located below spawning areas typically showing a larger concentration of carcasses compared to areas of increased velocity (runs and riffles).
We assumed the spatial distribution of fresh female carcasses provides evidence of relative spawning locations equally for hatchery-origin and natural-origin winter Chinook. This assumption should be valid unless post-spawning behavioral differences exist between hatchery-origin and natural-origin winter Chinook.

Spatial distribution of hatchery-origin and natural-origin carcasses was remarkably similar throughout the survey area including the area immediately below the Keswick Dam (RM 302) and extending down to the ACID Dam (RM 298.5). During the 2002 and 2003 surveys, a greater proportion of hatchery-origin carcasses were found within this reach compared to natural-origin fish.

Spawn Timing

Peak recovery of female hatchery-origin carcasses occurred approximately one week later than for female natural-origin carcasses. We assume the temporal occurrence of fresh female carcass recoveries provides evidence of spawn timing for hatchery-origin and natural-origin winter Chinook salmon. We have no evidence to suggest differences exist in post-spawning longevity between hatchery-origin and natural-origin winter Chinook salmon.

Gender Composition

Males comprised 42% of hatchery-origin and 29% of natural-origin carcasses recovered. These data suggest females are substantially more abundant or that the carcass survey may be biased against males. A greater abundance of females were recovered during the 2001 – 2003 carcass surveys as well. However, a skewed gender ratio is not supported by observations at the Keswick Dam and Red Bluff Diversion Dam fish traps. Since 2001, carcass survey staff have reported observing hatchery-origin and natural-origin spawned-out male Chinook salmon slowly swimming downstream while spawned-out females have been observed more frequently in the vicinity of newly constructed redds. These observations have led to the hypothesis that male Sacramento River winter Chinook salmon may exhibit a different post-spawn behavior than females. If males do tend to move downstream after spawning, they may be moving out of the survey area explaining the discrepancy in gender ratios between traps that capture pre-spawn fish (i.e., the traps at Red Bluff Diversion Dam and Keswick Dam) and the carcass survey. Consistent with this hypothesis, a greater proportion of male carcasses relative to female carcasses were recovered in the downstream-most reach of the survey area, although not in sufficient numbers to completely explain the differences in gender ratio. It is possible that males move even further downstream than sampled or exhibit some other behavioral difference. Additional research will be required to answer this question.

Spawn status

Hatchery-origin female carcasses were statistically more likely to be found unspawned when compared to natural-origin females; however, this difference was probably not biologically significant due to low numbers of both unspawned hatchery-origin and natural-origin female carcasses. Also, spawning success does not necessarily indicate that hatchery-origin and natural-origin fish are contributing equally to future generations. Several studies have shown that offspring from naturally reproducing hatchery-origin fish and matings between hatchery-origin and natural-origin fish may have lower survival than offspring of natural-origin fish (Waples 1991; Utter et al. 1993; Campton 1995). However, Ardren et al. (1999) found equal reproductive potential of hatchery-origin and natural-origin steelhead in the Hood River, Oregon. A literature review of Pacific Northwest salmonid hatcheries by Brannon et al. (2004) concluded that hatchery-origin fish, when properly propagated, have equal reproductive performance as wild fish. Rates of survival for progeny of naturally spawning hatchery-origin winter Chinook salmon in the upper Sacramento River are not known.

Length
Adult hatchery-origin males and females, and grilse hatchery-origin males returned at a smaller size than natural-origin fish of the same age and gender. We could not determine the reason for these differences using our data but, possible explanations include:

1) Hatchery-origin fish, upon release, may have difficulty transitioning to natural feeding strategies and therefore, have a reduced food consumption rate (Einum and Fleming 2001).

2) Hatchery-origin adults have been found to place more energy into development of gonadal tissue, as opposed to somatic tissue, when compared to natural-origin adults (Fleming and Gross 1992).

3) Hatchery-origin fish are more likely to return to fresh water earlier in the spawning season (Chandler and Bjornn 1988; Einum and Fleming 2000; Mackey et al. 2001). Fish returning early would not benefit from the additional feeding time under ocean conditions.

4) Fish exhibiting faster growth are more likely to return as grilse (Mullan et al. 1992; Silverstein et al. 1998; Larson et al. 2004). This occurs more often for males than females and in larger proportions for hatchery-origin rather than natural-origin fish (Larson et al. 2004). If this were to occur, a smaller proportion of fish predisposed for faster growth would be left in the hatchery-origin population relative to the natural-origin population.

Age Composition
Hatchery-origin and natural-origin grilse carcasses were almost exclusively male. Grilse males occurred nearly twice as often in the hatchery-origin male population (77.3%) compared to the natural-origin male population (39.3%). Larson et al. (2004) found that increased precocial maturation of hatchery-origin Chinook salmon was likely a result of accelerated growth in the hatchery environment.

Genetic Analyses
In past surveys (USFWS 2003, 2004a, 2004b), carcasses with an LOD score greater than zero were considered winter-run Chinook. Using this criterion potentially meant some fish assigned as winter-run might actually be from some other run (Figure 3). Because we felt it was more important to include only winter-run fish in our estimates, than it was to include all possible winter-run fish along with perhaps some other run of Chinook, we increased the LOD standard for classification as a winter-run Chinook salmon from a score greater than zero to a score greater than two in 2004. This resulted in a decrease in the proportion of fish classified in the overall population as winter Chinook salmon relative to previous years by about six percent. When an LOD score greater than zero was applied to the 2004 samples, the proportion of fish classified in the overall population as winter Chinook salmon was very similar to that estimated in previous years. The more conservative criterion for classifying fish as winter-run Chinook, combined with the high success rate (96.6%) in amplifying carcass DNA, provides compelling evidence that survey findings are descriptive of winter-run Chinook. The greater frequency of salmon identified as winter Chinook during the run peak (June and July), along with the smaller

abundance of salmon at the beginning and end of the survey, suggests the winter Chinook salmon spawning period was adequately surveyed during the carcass survey.

Gender determination using the GHpsi marker was accurate for the majority of carcasses tested. Compared to gender determinations based on phenotypic characteristics observed during the carcass survey, the GHpsi identified gender correctly 88% of the time. Genetic gender determination of broodstock fish were correct 91% of the time. This suggests that accuracy decreased only marginally when carcass DNA was used which could be a result of the carcass DNA condition, error in identifying gender in the field, or due to accuracy of using the GHpsi marker to identify gender.

Demographic benefit of hatchery supplementation

Hatchery-origin fish represented 8.1% of the total winter Chinook salmon spawning population in 2004. Additionally, hatchery supplementation resulted in nearly seven times the number of returns than if the fish collected for hatchery broodstock had been allowed to spawn naturally. The supplementation program succeeded in enhancing the run size of the winter Chinook salmon population in 2004.

Conclusions

Genetic analyses confirmed that data collected during the 2004 carcass survey was predominantly from winter-run Chinook salmon and that the winter-run was adequately surveyed spatially and temporally. The hatchery supplementation program at Livingston Stone NFH contributed about 8% of the estimated total return, and a representation of coded-wire tag recoveries across family groups suggested that the genetic diversity of the parental broodstock was represented in the 2004 returns. Spawning of hatchery-origin and natural-origin fish overlapped spatially and temporally. The number of female carcasses containing unspent eggs was small for both hatchery- and natural-origin fish indicating low pre-spawning mortality of both groups. Hatchery-origin returns were comprised of a higher proportion of Age-2 males than the natural-origin population. Also, hatchery-origin fish were smaller than natural-origin fish. Information collected in 2004 was consistent with the hypothesis that male winter-run Chinook salmon may exhibit different post-spawning behavior than females, affecting gender ratios estimated from the survey, but additional research will be required to resolve this issue.

Notes on apparent inconsistencies between the Sacramento River winter Chinook salmon carcass survey and fish trapping at the Keswick Dam

Winter Chinook salmon broodstock collection at Keswick Dam Fish Trap

Keswick Dam (RM 302) is a barrier to fish passage and represents the upstream migration limit for anadromous salmonids in the Sacramento River. The fish trap at Keswick Dam is used to capture broodstock for the winter Chinook salmon supplementation program. Broodstock collection activities for winter Chinook salmon are conducted according to an annual Adult Collection Plan that identifies monthly broodstock collection targets for January through July. Winter Chinook salmon in excess of broodstock needs (or in excess of monthly targets) and non-winter Chinook salmon were returned to the Sacramento River either at Posse Grounds boat ramp (RM 297) or Caldwell Park boat ramp (RM 298), depending on flow. Fish were floy tagged before release into the river.

Spatial distribution of hatchery-origin carcasses

During 2004, hatchery-origin winter Chinook salmon (n = 224) comprised 45.1% of the 497 Chinook salmon trapped at the Keswick Dam Fish Trap (KDFT). During the carcass survey, fresh hatchery-origin carcasses (n = 130) represented only 8.0% of the total fresh carcasses (n = 1,622) recovered. These data suggest that hatchery-origin winter Chinook returned to the terminus of migration in the Sacramento River at a higher rate than elsewhere in the river.

Recoveries of floy tagged fish released from the Keswick Dam Fish Trap

During 2004, a total of 261 genetically identified winter Chinook salmon were captured at the KDFT, floy tagged, and then released back into the Sacramento River. Ten of these tagged fish were subsequently recovered on the carcass survey (Table 4), for a recovery rate of 3.8%. This is in contrast to a recovery rate of approximately 55% for Chinook salmon that were tagged as part of the carcass survey mark-recapture estimate (Killam 2005). During the carcass survey, 2,062 adult natural-origin carcasses were tagged, of which 1,128 were subsequently recovered giving a recovery rate of 54.7%. Considering only fresh natural-origin carcasses, the recovery rate was similar with 768 recoveries out of a total of 1,381 fresh carcasses tagged (55.6%).

Several hypotheses have been proposed to explain the discrepancy between recovery rates for floy tagged fish released from the KDFT and carcasses tagged as part of the mark-recapture survey. These include: 1) live fish released from the KDFT may shed their floy tags during spawning activities, or post-spawning as their body condition deteriorates, 2) the fish released from the KDFT may spawn in the deep water areas immediately below Keswick Dam where their carcasses may be unlikely to be recovered due to the river's morphology, or 3) the fish released from the KDFT may fall back below the survey areas due to the stress of being captured, transported, tissue sampled, tagged, and released.

Table 4. Floy tag and date of capture for Chinook salmon captured at the Keswick Dam fish trap, location (boat ramp and river mile [RM]) and date of release back into the Sacramento River, and location (RM) and date the carcass was recovered during the 2004 upper Sacramento River winter Chinook salmon carcass survey.

Floy Tag		Released			Recovered	
Number	Tag Date	Boat Ramp	RM	Date	RM	Date
OR-209	3/23/2004	Caldwell Park	298	3/25/2004	300	5/25/2004
OR-217	3/23/2004	Caldwell Park	298	3/25/2004	294	6/8/2004
OR-289	3/31/2004	Posse Grounds	297	3/31/2004	296.5	6/9/2004
W-042	5/11/2004	Caldwell Park	298	5/11/2004	298	6/12/2004
W-054	5/11/2004	Caldwell Park	298	5/11/2004	295	6/26/2004
W-079	5/25/2004	Caldwell Park	298	5/27/2004	294	7/8/2004
W-084	5/25/2004	Posse Grounds	297	5/25/2004	298	7/12/2004
W-172	6/2/2004	Posse Grounds	297	6/2/2004	294	7/14/2004
W-224	6/8/2004	Posse Grounds	297	6/8/2004	299	7/30/2004
W-298	6/15/2004	Posse Grounds	297	6/15/2004	296	6/29/2004

Recommendations

To address these issues, we recommend that additional research be conducted to assess the abundance and composition of that segment of the winter Chinook salmon population that returns to the uppermost section of the Sacramento River, between the Anderson-Cottonwood Irrigation District Diversion Dam and the Keswick Dam. We believe that the fish ladders at the Anderson-Cottonwood Irrigation District Diversion Dam may provide a valuable monitoring location for winter Chinook salmon beginning in April when the flashboards are installed. Additional research using radio telemetry would allow the documentation of winter Chinook salmon movements in the upper Sacramento River. These studies have the potential to provide valuable insights into possible biases associated with winter Chinook salmon population estimates in the upper Sacramento River based on the mark-recapture methods.

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Appendix A. Analysis of run size benefits resulting from the winter Chinook salmon supplementation program at Livingston Stone NFH based on the 2004 upper Sacramento River winter Chinook salmon carcass survey. Analysis includes estimation of winter Chinook salmon escapement in absence of a supplementation program (Appendix A-1), estimation of hatchery-origin winter Chinook salmon escapement with the existing supplementation program (Appendix A-2), and a comparison of these two estimates (Appendix A-3).

Appendix A-1. Estimation of the 2004 winter Chinook salmon escapement in absence of a supplementation program.

Methods and Equations

We estimated the number of natural-origin fish that would have returned without supplementation from Livingston Stone NFH. More specifically, we estimated the number of natural-origin offspring that would have been produced by fish retained for hatchery broodstock had these fish been allowed to spawn naturally. We first calculated the abundance of each age class (n_A):

$$n_A = JS_{Total} \times A_P \qquad (1)$$

where,

JS_{Total} = total winter Chinook salmon population (as estimated by the Jolly-Seber method) and

A_P = proportion of each age class present in the overall population (assumed: 0.25 age-2, 0.67 age-3, and 0.08 age-4 [Hallock and Fisher 1985]).

Replacement rates for each age class (r_A) were then estimated:

$$r_A = n_A / JS_{BY} \qquad (2)$$

where,

JS_{BY} = total winter Chinook salmon escapement estimate (as estimated by the Jolly-Seber method) for the corresponding brood year. For example, for fish returning in 2004 the corresponding brood year is: 2002 for age-2, 2001 for age-3, and 2000 for age-4.

For each age, we estimated the expected number of adult returns (N_{Age}) that would have resulted had the adults retained for broodstock in previous years been allowed to spawn naturally:

$$N_{Age} = r_A \times n_B \qquad (3)$$

where,

n_B = number of adults retained as hatchery broodstock for the corresponding brood year. For example, for fish returning in 2004 the corresponding brood year is: 2002 for age-2, 2001 for age-3, and 2000 for age-4.

Summing across years, we estimated the total expected number of natural-origin adult returns (N_{Final}) that would have resulted had the adults retained for broodstock in previous years been allowed to spawn naturally:

$N_{Final} = \Sigma (N_{Age}).$ (4)

Data and Calculations

	JS_{Total}	=	**7,869**	**=**	2004 Total escapement
2 year old	JS_{BY}	=	**7,464**	**=**	2002 Total escapement
3 year old	JS_{BY}	=	**8,224**	**=**	2001 Total escapement
4 year old	JS_{BY}	=	**6,028**	**=**	2000 Total escapement
2 year old	n_B	=	**96**	**=**	2002 Adult broodstock
3 year old	n_B	=	**98**	**=**	2001 Adult broodstock
4 year old	n_B	=	**83**	**=**	2000 Adult broodstock

Age Composition

P_{Total}	×	A_P	=	n_A		
7,869	×	0.25	=	**1,967.2500**	=	2004 , 2 year old escapement
7,869	×	0.67	=	**5,272.2300**	=	2004 , 3 year old escapement
7,869	×	0.08	=	**629.5200**	=	2004 , 4 year old escapement

Contribution Rate

n_A	/	P_{BY}	=	r_A		
1,967.2500	/	7,464	=	**0.2636**	=	2002 Contribution rate
5,272.2300	/	8,224	=	**0.6411**	=	2001 Contribution rate
629.5200	/	6,028	=	**0.1044**	=	2000 Contribution rate

Recruitment of Adults

r_A	×	n_B	=	N_{Age}		
0.2636	×	96	=	**25.3023**	=	2002 Adult Returns
0.6411	×	98	=	**62.8257**	=	2001 Adult Returns
0.1044	×	83	=	**8.6679**	=	2000 Adult Returns
				96.7959	**=**	$\mathbf{N_{Final}}$

Appendix A-2. Estimated escapement of hatchery-origin winter Chinook salmon in the upper Sacramento River for 2004.

Methods and Equations

We estimated total abundance of hatchery-origin winter Chinook salmon returning to the upper Sacramento River in 2004 by using a series of expansions to correct for biases and incomplete counts associated with the carcass survey. Beginning with the number of hatchery-origin Chinook observed during the survey, we first expanded to include unrecognized fin clips and undetected coded-wire tags in non-fresh carcasses. Secondly, we expanded our estimate to include carcasses not observed during the survey. Thirdly, hatchery-origin fish that were captured for use as broodstock at the Livingston Stone NFH were added in to the estimate. Lastly, we expanded to include hatchery-origin fish that did not have a clipped adipose fin. Rationale and descriptions of these expansions are contained in the following sections:

1. Based on observations from previous years, we believe there is a decreased likelihood for recovering a coded-wire tag in non-fresh carcasses compared to a fresh carcasses. We also believe an adipose fin clip is more likely to be identified among fresh carcasses compared to non-fresh carcasses. To account for these biases, we expanded non-fresh hatchery-origin carcasses recovered during the carcass survey based on the recovery rates observed for fresh hatchery-origin carcass recoveries ($H_{NF\text{-}Exp}$):

$$H_{NF\text{-}Exp} = (H_{F\text{-}Obs} \times T_{NF\text{-}Obs}) / T_{F\text{-}Obs} \qquad (5)$$

where,

$H_{F\text{-}Obs}$ = number of fresh hatchery-origin carcasses,

$T_{NF\text{-}Obs}$ = total number of non-fresh hatchery-origin and natural-origin carcasses, and

$T_{F\text{-}Obs}$ = total number of fresh hatchery-origin and natural-origin carcasses recovered during the carcass survey.

2. We then expanded to include hatchery-origin carcasses believed to be present in the upper Sacramento River population but not observed during the survey (H_{Sac}). This expansion is based on the proportion of hatchery-origin carcasses observed during the carcass survey to the total estimated escapement of naturally reproducing winter Chinook salmon in the upper Sacramento River, based on the Jolly-Seber population estimate($N_{J\text{-}S}$):

$$H_{Sac} = (H_{NF\text{-}Exp} + H_{F\text{-}Obs}) / T_{Obs} \times N_{J\text{-}S} \qquad (6)$$

where,

T_{Obs} = the total number of carcasses observed during the carcass survey (including fresh and non-fresh and hatchery-origin and natural-origin carcasses).

3. Hatchery-origin fish that were captured for use as broodstock at the Livingston Stone NFH ($LSNFH_H$) and those observed in the carcass survey where the carcass condition was not determined (H_{Unk}) were accounted for by adding them to H_{Sac}. This yielded the total number of adipose fin clipped hatchery-origin fish present in the upper Sacramento River and at the Livingston Stone NFH (H_{Clip}):

$$H_{Clip} = H_{Sac} + LSNFH_H + H_{Unk} \tag{7}$$

4. To account for non-adipose fin clipped hatchery-origin fish, we expanded H_{Clip} based on mark retention rates measured prior to release of juvenile winter Chinook. To accomplish this, we must first apportion H_{Clip} among each tag code recovered (CWT_{App}):

$$CWT_{App} = H_{Clip} \times (CWT_{Rec} / CWT_T) \tag{8}$$

where,

CWT_{Rec} = the number of coded-wire tags recovered for an individual tag code and

CWT_T = the total number of all coded-wire tags recovered.

5. We can now expand CWT_{App} to include all hatchery-origin fish without an adipose fin clip (CWT_{Final}) based on tag retention rates measured prior to release of juvenile winter Chinook.

$$CWT_{Final} = CWT_{App} / (J_{Clip} / J_{Obs}) \tag{9}$$

where,

J_{Clip} = the number of juveniles observed with an adipose fin clip during tag retention studies prior to release, by individual tag code and

J_{Obs} = the total number of juveniles observed during tag retention studies prior to release, by individual tag code.

6. Lastly, we sum CWT_{Final} to obtain our final hatchery-origin winter Chinook salmon population estimate (H_{Final}).

$$H_{Final} = \Sigma \, CWT_{Final} \tag{10}$$

Data

130 =	$H_{F\text{-}Obs}$	=	Number of fresh hatchery carcass recoveries
1,656 =	$T_{NF\text{-}Obs}$	=	Number of non-fresh hatchery and natural carcass recoveries
1,621 =	$T_{F\text{-}Obs}$	=	Number of fresh hatchery and natural carcass recoveries
3,278 =	T_{Obs}	=	Total carcasses observed during the carcass survey
7,784 =	$N_{J\text{-}S}$	=	Total naturally reproducing winter Chinook salmon escapement
8 =	$LSNFH_H$	=	Hatchery fish retained for LSNFH broodstock
1 =	H_{Unk}	=	Total hatchery fish with unknown carcass condition

For calculations using 'Juvenile Tag Retention Data':

C = fish with an adipose fin clip
NC = fish with no adipose fin clip
T = fish with a coded-wire tag
NT = fish with no coded-wire tag

	CWT$_{Rec}$		Juvenile tag retention data			
CWTCode	Survey	LSNFH	T/C	NT/C	T/NC	NT/NC
0501030108	1	0	192	8	0	0
0501030307	1	0	196	4	0	0
0501030705	19	4	395	3	1	1
0501030706	20	2	968	18	10	4
0501030707	10	0	200	0	0	0
0501030709	5	0	180	20	0	0
0501030802	2	0	188	12	0	0
0501030803	3	0	184	16	0	0
0501030804	2	0	178	22	0	0
0501030805	3	0	194	6	0	0
0501030806	2	0	188	12	0	0
0501030807	5	0	194	6	0	0
0501030808	1	0	199	1	0	0
0501030902	2	0	187	13	0	0
0501030903	6	1	193	7	0	0
0501030904	2	0	190	9	1	0
0501030905	1	0	186	13	1	0
0501030906	1	1	185	13	2	0
0501030907	2	0	180	19	1	0
0501030908	5	0	180	18	1	1
0501040101	3	0	199	1	0	0
0501040102	2	0	199	1	0	0
0501040103	3	0	194	2	4	0
0501040104	3	0	198	0	2	0
051278	1	0	194	6	0	0
051279	1	0	187	13	0	0
051280	6	0	192	8	0	0
051282	2	0	182	17	1	0
051283	1	0	172	27	1	0
051284	8	0	182	18	0	0
051286	2	0	195	5	0	0
051287	2	0	170	30	0	0
051288	3	0	180	20	0	0
051291	3	0	195	5	0	0
051294	4	0	191	9	0	0
051296	4	0	190	10	0	0
051297	3	0	187	13	0	0
051298	3	0	193	2	5	0
051299	3	0	197	3	0	0
051365	2	0	184	16	0	0
051367	1	0	194	6	0	0
051371	1	0	188	10	2	0
051372	2	0	195	4	1	0
053737	7	0	198	2	0	0
	163	8				

Calculations

1. Non-fresh carcass expansion based on fresh carcass recovery rate

$$\left(\overset{H_{F\text{-}Obs}}{\overline{130}} \times \overset{T_{NF\text{-}Obs}}{\overline{1{,}656}} \right) / \overset{T_{F\text{-}Obs}}{\overline{1{,}621}} = \overset{H_{NF\text{-}Exp}}{\overline{\mathbf{132.8069}}}$$

2. Expansion to include carcasses not observed

$$\left(\overset{H_{NF\text{-}Exp}}{\overline{132.8069}} + \overset{H_{F\text{-}Obs}}{\overline{130}} \right) / \overset{T_{Obs}}{\overline{3{,}278}} \times \overset{N_{J\text{-}S}}{\overline{7{,}784}} = \overset{H_{Sac}}{\overline{\mathbf{624.0662}}}$$

3. Addition of hatchery-origin fish retained for Livingston Stone NFH broodstock and unknown condition hatchery-origin fish

$$\overset{H_{Sac}}{\overline{624.0662}} + \overset{LSNFH_{H}}{\overline{8}} + \overset{H_{Unk}}{\overline{1}} = \overset{H_{Clip}}{\overline{\mathbf{633.0662}}}$$

4. Apportioning by tag code

CWTCode		H_{Clip}			CWT_{Rec}		CWT_T			CWT_{App}
0501030108	:	633.0662	×	(	1	/	171	)	=	**3.7021**
0501030307	:	633.0662	×	(	1	/	171	)	=	**3.7021**
0501030705	:	633.0662	×	(	23	/	171	)	=	**85.1493**
0501030706	:	633.0662	×	(	22	/	171	)	=	**81.4471**
0501030707	:	633.0662	×	(	10	/	171	)	=	**37.0214**
0501030709	:	633.0662	×	(	5	/	171	)	=	**18.5107**
0501030802	:	633.0662	×	(	2	/	171	)	=	**7.4043**
0501030803	:	633.0662	×	(	3	/	171	)	=	**11.1064**
0501030804	:	633.0662	×	(	2	/	171	)	=	**7.4043**
0501030805	:	633.0662	×	(	3	/	171	)	=	**11.1064**
0501030806	:	633.0662	×	(	2	/	171	)	=	**7.4043**
0501030807	:	633.0662	×	(	5	/	171	)	=	**18.5107**
0501030808	:	633.0662	×	(	1	/	171	)	=	**3.7021**
0501030902	:	633.0662	×	(	2	/	171	)	=	**7.4043**
0501030903	:	633.0662	×	(	7	/	171	)	=	**25.9150**
0501030904	:	633.0662	×	(	2	/	171	)	=	**7.4043**
0501030905	:	633.0662	×	(	1	/	171	)	=	**3.7021**
0501030906	:	633.0662	×	(	2	/	171	)	=	**7.4043**
0501030907	:	633.0662	×	(	2	/	171	)	=	**7.4043**
0501030908	:	633.0662	×	(	5	/	171	)	=	**18.5107**
0501040101	:	633.0662	×	(	3	/	171	)	=	**11.1064**
0501040102	:	633.0662	×	(	2	/	171	)	=	**7.4043**
0501040103	:	633.0662	×	(	3	/	171	)	=	**11.1064**
0501040104	:	633.0662	×	(	3	/	171	)	=	**11.1064**
051278	:	633.0662	×	(	1	/	171	)	=	**3.7021**
051279	:	633.0662	×	(	1	/	171	)	=	**3.7021**
051280	:	633.0662	×	(	6	/	171	)	=	**22.2128**
051282	:	633.0662	×	(	2	/	171	)	=	**7.4043**
051283	:	633.0662	×	(	1	/	171	)	=	**3.7021**
051284	:	633.0662	×	(	8	/	171	)	=	**29.6171**
051286	:	633.0662	×	(	2	/	171	)	=	**7.4043**
051287	:	633.0662	×	(	2	/	171	)	=	**7.4043**
051288	:	633.0662	×	(	3	/	171	)	=	**11.1064**
051291	:	633.0662	×	(	3	/	171	)	=	**11.1064**
051294	:	633.0662	×	(	4	/	171	)	=	**14.8086**
051296	:	633.0662	×	(	4	/	171	)	=	**14.8086**
051297	:	633.0662	×	(	3	/	171	)	=	**11.1064**
051298	:	633.0662	×	(	3	/	171	)	=	**11.1064**
051299	:	633.0662	×	(	3	/	171	)	=	**11.1064**
051365	:	633.0662	×	(	2	/	171	)	=	**7.4043**
051367	:	633.0662	×	(	1	/	171	)	=	**3.7021**
051371	:	633.0662	×	(	1	/	171	)	=	**3.7021**
051372	:	633.0662	×	(	2	/	171	)	=	**7.4043**
053737	:	633.0662	×	(	7	/	171	)	=	**25.9150**
										633.0662

5. Expansion to include hatchery-origin fish without an adipose fin clip

CWTCode		CWT_{App}		J_{Clip}		J_{Obs}			CWT_{Final}
0501030108	:	3.7021	/ (	200	/	200	)	=	**3.7021**
0501030307	:	3.7021	/ (	200	/	200	)	=	**3.7021**
0501030705	:	85.1493	/ (	398	/	400	)	=	**85.5771**
0501030706	:	81.4471	/ (	986	/	1000	)	=	**82.6036**
0501030707	:	37.0214	/ (	200	/	200	)	=	**37.0214**
0501030709	:	18.5107	/ (	200	/	200	)	=	**18.5107**
0501030802	:	7.4043	/ (	200	/	200	)	=	**7.4043**
0501030803	:	11.1064	/ (	200	/	200	)	=	**11.1064**
0501030804	:	7.4043	/ (	200	/	200	)	=	**7.4043**
0501030805	:	11.1064	/ (	200	/	200	)	=	**11.1064**
0501030806	:	7.4043	/ (	200	/	200	)	=	**7.4043**
0501030807	:	18.5107	/ (	200	/	200	)	=	**18.5107**
0501030808	:	3.7021	/ (	200	/	200	)	=	**3.7021**
0501030902	:	7.4043	/ (	200	/	200	)	=	**7.4043**
0501030903	:	25.9150	/ (	200	/	200	)	=	**25.9150**
0501030904	:	7.4043	/ (	199	/	200	)	=	**7.4415**
0501030905	:	3.7021	/ (	199	/	200	)	=	**3.7207**
0501030906	:	7.4043	/ (	198	/	200	)	=	**7.4791**
0501030907	:	7.4043	/ (	199	/	200	)	=	**7.4415**
0501030908	:	18.5107	/ (	198	/	200	)	=	**18.6977**
0501040101	:	11.1064	/ (	200	/	200	)	=	**11.1064**
0501040102	:	7.4043	/ (	200	/	200	)	=	**7.4043**
0501040103	:	11.1064	/ (	196	/	200	)	=	**11.3331**
0501040104	:	11.1064	/ (	198	/	200	)	=	**11.2186**
051278	:	3.7021	/ (	200	/	200	)	=	**3.7021**
051279	:	3.7021	/ (	200	/	200	)	=	**3.7021**
051280	:	22.2128	/ (	200	/	200	)	=	**22.2128**
051282	:	7.4043	/ (	199	/	200	)	=	**7.4415**
051283	:	3.7021	/ (	199	/	200	)	=	**3.7207**
051284	:	29.6171	/ (	200	/	200	)	=	**29.6171**
051286	:	7.4043	/ (	200	/	200	)	=	**7.4043**
051287	:	7.4043	/ (	200	/	200	)	=	**7.4043**
051288	:	11.1064	/ (	200	/	200	)	=	**11.1064**
051291	:	11.1064	/ (	200	/	200	)	=	**11.1064**
051294	:	14.8086	/ (	200	/	200	)	=	**14.8086**
051296	:	14.8086	/ (	200	/	200	)	=	**14.8086**
051297	:	11.1064	/ (	200	/	200	)	=	**11.1064**
051298	:	11.1064	/ (	195	/	200	)	=	**11.3912**
051299	:	11.1064	/ (	200	/	200	)	=	**11.1064**
051365	:	7.4043	/ (	200	/	200	)	=	**7.4043**
051367	:	3.7021	/ (	200	/	200	)	=	**3.7021**
051371	:	3.7021	/ (	198	/	200	)	=	**3.7395**
051372	:	7.4043	/ (	199	/	200	)	=	**7.4415**
053737	:	25.9150	/ (	200	/	200	)	=	**25.9150**

6. H_{Final} = **635.7594**

Appendix A-3. Comparison of estimated escapement with and without the supplementation program in the upper Sacramento River for 2004.

Methods and Equations

To determine the number of hatchery-origin winter Chinook salmon returning at each age (H_{Age}), we multiplied the estimated total hatchery-origin adults (H_{Final}) by the expected proportions returning at each age (Hallock and Fisher 1985):

$$H_{Age} = H_{Final} \times A_P. \tag{11}$$

We can then compare our estimated returns in absence of the supplementation program to returns with the existing program.

Data and Calculations

Appendix A-1

Age (yr)	$\mathbf{N_{Age}}$		
2 (from year 2002 adults)	**25.3023**		
3 (from year 2001 adults)	**62.8257**		
4 (from year 2000 adults)	**8.6679**		
	96.7959	=	$\mathbf{N_{Final}}$

Appendix A-2

Age (yr)	$\mathbf{H_{Age}}$		H_{Final}		A_P
2 (from year 2002 adults)	**158.9398**	=	635.7594	×	0.25
3 (from year 2001 adults)	**425.9588**	=	635.7594	×	0.67
4 (from year 2000 adults)	**50.8607**	=	635.7594	×	0.08

Comparison of Appendix A-1 and A-2

Age (year)	Natural	Hatchery	Percent Increase
2	25.3	158.9	528.1
3	62.8	426.0	578.3
4	8.7	50.9	485.1
Total	**97**	**636**	**557**

An estimated 97 fish would have returned without the supplementation program (Appendix A-1), however, an estimated 636 hatchery-origin fish returned in 2004. Offspring of the winter Chinook salmon adults used as broodstock for propagation at Livingston Stone NFH produced a return 557% greater than the estimated escapement if these adults had been allowed to spawn naturally.

Appendix B. Recovery information for carcasses containing a coded-wire tag (CWT) collected during the 2004 upper Sacramento River winter Chinook salmon carcass survey. Data includes river mile (RM) of recovery and carcass gender, fork length (FL, mm), condition (see text [Methods] for description), and spawn status. All fish were winter Chinook salmon originating from Livingston Stone National Fish Hatchery.

Collection Date	CWT Code	RM	Sex	FL	Condition	Spawn Status
5/12/2004	050768	299	Female	760	Fresh	Spawned
5/25/2004	0501040103	300	Female	705	Fresh	Spawned
6/2/2004	0501040102	295	Female	765	Fresh	Unspawned
6/6/2004	0501030705	297	Female	720	Fresh	Spawned
6/15/2004	051284	299	Male	551	Fresh	Unknown
6/17/2004	0501030706	287	Male	850	Fresh	Unknown
6/20/2004	0501040101	291	Female	781	Non-Fresh	Spawned
6/21/2004	051284	297	Male	575	Fresh	Unknown
6/23/2004	051284	294	Male	540	Non-Fresh	Unknown
6/24/2004	0501030706	297	Female	793	Fresh	Spawned
6/26/2004	051284	296	Male	535	Fresh	Unknown
6/26/2004	0501030707	296	Male	806	Fresh	Unknown
6/26/2004	0501030709	288	Male	710	Fresh	Unknown
6/27/2004	0501030803	297	Female	708	Fresh	Spawned
6/27/2004	0501030707	298	Female	710	Fresh	Spawned
6/28/2004	0501040101	278	Female	643	Fresh	Unspawned
6/28/2004	051284	286	Male	530	Fresh	Unknown
6/29/2004	051282	294	Male	510	Non-Fresh	Unknown
6/29/2004	051284	295	Male	580	Fresh	Unknown
6/29/2004	0501030705	288	Female	738	Non-Fresh	Spawned
6/29/2004	051297	296	Male	570	Fresh	Unknown
6/30/2004	0501040104	300	Female	700	Fresh	Unspawned
7/1/2004	051299	282	Male	520	Non-Fresh	Unknown
7/2/2004	0501030709	291	Female	590	Fresh	Spawned
7/2/2004	0501030908	288	Male	830	Fresh	Unknown
7/3/2004	051284	297	Male	610	Fresh	Unknown
7/3/2004	051299	300	Male	490	Fresh	Unknown
7/3/2004	051296	297	Male	540	Non-Fresh	Unknown
7/3/2004	0501030807	296	Male	800	Non-Fresh	Unknown
7/5/2004	051291	295	Male	580	Fresh	Unknown
7/5/2004	0501030707	287	Female	625	Unknown	Spawned
7/5/2004	0501030807	295	Female	700	Fresh	Spawned
7/5/2004	051298	296	Male	580	Non-Fresh	Unknown
7/5/2004	051299	291	Male	530	Fresh	Unknown
7/6/2004	0501030108	297	Female	859	Non-Fresh	Spawned
7/6/2004	0501030705	297	Female	670	Fresh	Spawned

Collection Date	CWT Code	RM	Sex	FL	Condition	Spawn Status
7/6/2004	0501030903	297	Female	680	Fresh	Spawned
7/6/2004	051291	299	Male	615	Fresh	Unknown
7/6/2004	0501030709	297	Male	660	Non-Fresh	Unknown
7/8/2004	053737	294	Male	545	Fresh	Unknown
7/8/2004	051282	289	Male	470	Non-Fresh	Unknown
7/8/2004	0501030806	295	Female	678	Non-Fresh	Spawned
7/8/2004	051280	295	Male	462	Fresh	Unknown
7/8/2004	0501030707	294	Male	880	Fresh	Unknown
7/9/2004	051286	297	Male	615	Non-Fresh	Unknown
7/9/2004	051294	297	Male	503	Fresh	Unknown
7/9/2004	051279	297	Male	510	Fresh	Unknown
7/9/2004	051294	298	Male	480	Non-Fresh	Unknown
7/9/2004	0501030802	297	Female	800	Non-Fresh	Spawned
7/9/2004	0501030803	299	Female	690	Non-Fresh	Spawned
7/9/2004	0501030804	298	Female	740	Non-Fresh	Spawned
7/9/2004	0501030707	299	Female	745	Fresh	Spawned
7/10/2004	051365	287	Male	495	Fresh	Unknown
7/10/2004	051365	286	Male	462	Non-Fresh	Unknown
7/10/2004	051296	286	Male	577	Fresh	Unknown
7/11/2004	0501030907	288	Female	750	Fresh	Spawned
7/11/2004	051278	288	Male	580	Fresh	Unknown
7/11/2004	0501030709	294	Female	700	Non-Fresh	Spawned
7/11/2004	051287	287	Male	575	Fresh	Unknown
7/11/2004	0501030705	293	Female	736	Fresh	Spawned
7/11/2004	051372	296	Male	505	Fresh	Unknown
7/11/2004	0501030705	296	Female	729	Fresh	Spawned
7/12/2004	0501040102	298	Female	654	Fresh	Spawned
7/12/2004	0501030802	301	Female	735	Fresh	Spawned
7/12/2004	051297	300	Male	635	Non-Fresh	Unknown
7/12/2004	0501030807	297	Male	820	Non-Fresh	Unknown
7/12/2004	0501030707	298	Female	686	Fresh	Spawned
7/12/2004	0501030706	297	Female	800	Fresh	Spawned
7/12/2004	051288	298	Male	570	Fresh	Unknown
7/12/2004	0501030903	297	Male	831	Fresh	Unknown
7/13/2004	0501030706	282	Male	751	Non-Fresh	Unknown
7/13/2004	051297	283	Male	585	Non-Fresh	Unknown
7/14/2004	051294	294	Male	490	Non-Fresh	Unknown
7/14/2004	051286	296	Male	630	Fresh	Unknown
7/14/2004	0501030908	295	Female	739	Non-Fresh	Spawned
7/14/2004	0501030705	295	Female	739	Fresh	Spawned
7/14/2004	0501030903	295	Female	740	Non-Fresh	Spawned

Collection Date	CWT Code	RM	Sex	FL	Condition	Spawn Status
7/14/2004	051280	288	Male	462	Non-Fresh	Unknown
7/14/2004	051367	287	Male	604	Non-Fresh	Unknown
7/14/2004	051298	295	Male	581	Non-Fresh	Unknown
7/15/2004	0501030705	297	Female	760	Fresh	Spawned
7/15/2004	0501030707	297	Female	738	Fresh	Spawned
7/15/2004	0501030908	297	Female	750	Fresh	Spawned
7/15/2004	051287	297	Male	470	Fresh	Unknown
7/15/2004	051288	297	Male	585	Fresh	Unknown
7/15/2004	0501030906	297	Male	850	Fresh	Unknown
7/15/2004	0501030706	297	Male	870	Non-Fresh	Unknown
7/15/2004	0501040103	297	Female	790	Non-Fresh	Spawned
7/15/2004	0501030803	298	Female	740	Fresh	Spawned
7/15/2004	0501030706	299	Female	720	Fresh	Spawned
7/15/2004	053737	297	Male	441	Fresh	Unknown
7/17/2004	051296	291	Male	640	Non-Fresh	Unknown
7/17/2004	0501030806	295	Female	773	Fresh	Spawned
7/17/2004	0501030707	292	Female	740	Non-Fresh	Spawned
7/17/2004	051284	288	Male	570	Fresh	Unknown
7/17/2004	0501030808	295	Female	770	Fresh	Spawned
7/18/2004	0501030908	297	Female	720	Fresh	Spawned
7/18/2004	0501030705	300	Female	720	Non-Fresh	Spawned
7/18/2004	0501030707	300	Female	696	Non-Fresh	Spawned
7/18/2004	0501030903	297	Female	757	Non-Fresh	Spawned
7/18/2004	0501040104	297	Female	793	Fresh	Spawned
7/18/2004	0501030705	297	Female	742	Fresh	Spawned
7/18/2004	0501030706	296	Female	758	Fresh	Spawned
7/18/2004	0501030706	297	Female	700	Fresh	Spawned
7/18/2004	0501030903	297	Female	640	Fresh	Spawned
7/18/2004	0501030709	296	Female	810	Fresh	Spawned
7/18/2004	0501030705	297	Female	680	Non-Fresh	Spawned
7/19/2004	0501030805	279	Female	791	Non-Fresh	Spawned
7/20/2004	0501030707	295	Male	896	Fresh	Unknown
7/20/2004	0501030705	294	Female	780	Non-Fresh	Spawned
7/20/2004	051294	294	Male	515	Non-Fresh	Unknown
7/20/2004	0501030705	290	Female	705	Fresh	Spawned
7/20/2004	0501030706	289	Male	839	Non-Fresh	Unknown
7/20/2004	051371	293	Male	510	Fresh	Unknown
7/21/2004	0501030904	297	Female	721	Fresh	Spawned
7/21/2004	051296	299	Male	450	Fresh	Unknown
7/21/2004	0501030804	297	Female	760	Fresh	Spawned
7/21/2004	0501030706	297	Female	669	Fresh	Spawned

Collection Date	CWT Code	RM	Sex	FL	Condition	Spawn Status
7/21/2004	0501030706	297	Female	741	Fresh	Spawned
7/21/2004	0501030705	298	Female	680	Fresh	Spawned
7/21/2004	0501030706	301	Female	722	Non-Fresh	Spawned
7/21/2004	053737	297	Male	460	Non-Fresh	Unknown
7/21/2004	0501030807	297	Male	735	Non-Fresh	Unknown
7/23/2004	053737	296	Male	550	Non-Fresh	Unknown
7/23/2004	051283	296	Male	591	Non-Fresh	Unknown
7/23/2004	0501030805	287	Female	740	Non-Fresh	Spawned
7/23/2004	0501030908	295	Female	750	Non-Fresh	Spawned
7/24/2004	0501030902	298	Female	701	Non-Fresh	Spawned
7/24/2004	0501030705	297	Female	612	Non-Fresh	Spawned
7/24/2004	0501030705	297	Female	670	Fresh	Spawned
7/24/2004	053737	297	Male	570	Fresh	Unknown
7/24/2004	0501030706	301	Female	770	Fresh	Spawned
7/24/2004	051280	297	Male	550	Non-Fresh	Unknown
7/24/2004	0501030907	297	Female	708	Non-Fresh	Spawned
7/25/2004	0501030903	281	Male	802	Non-Fresh	Unknown
7/26/2004	051291	291	Male	607	Non-Fresh	Unknown
7/27/2004	0501030706	297	Female	760	Fresh	Spawned
7/27/2004	0501030706	297	Female	520	Non-Fresh	Spawned
7/27/2004	051280	297	Male	540	Non-Fresh	Unknown
7/27/2004	051372	297	Male	550	Fresh	Unknown
7/28/2004	0501040101	279	Male	735	Fresh	Unknown
7/29/2004	051280	294	Male	539	Fresh	Unknown
7/29/2004	0501030705	295	Female	760	Fresh	Spawned
7/30/2004	051288	299	Female	557	Non-Fresh	Spawned
7/30/2004	0501030706	297	Female	670	Fresh	Spawned
7/30/2004	0501030705	297	Female	711	Fresh	Spawned
7/30/2004	0501030307	297	Female	840	Non-Fresh	Spawned
7/30/2004	051280	297	Male	520	Fresh	Unknown
8/2/2004	0501030705	299	Female	770	Non-Fresh	Spawned
8/2/2004	0501030805	297	Female	775	Fresh	Spawned
8/2/2004	0501030706	300	Female	810	Fresh	Spawned
8/2/2004	0501030706	299	Female	762	Fresh	Spawned
8/2/2004	0501030706	296	Female	700	Fresh	Spawned
8/2/2004	0501030807	297	Female	752	Non-Fresh	Spawned
8/2/2004	0501040104	297	Female	725	Non-Fresh	Spawned
8/2/2004	0501030904	297	Female	753	Non-Fresh	Spawned
8/2/2004	0501040103	297	Female	730	Non-Fresh	Spawned
8/5/2004	053737	298	Male	570	Fresh	Unknown
8/6/2004	051298	278	Male	546	Fresh	Unknown

Collection Date	CWT Code	RM	Sex	FL	Condition	Spawn Status
8/7/2004	0501030705	295	Female	780	Non-Fresh	Spawned
8/7/2004	0501030905	295	Female	711	Non-Fresh	Spawned
8/8/2004	053737	298	Male	589	Fresh	Unknown
8/8/2004	0501030902	296	Female	750	Non-Fresh	Spawned

Appendix C. Winter Chinook salmon tag code groups released from Livingston Stone National Fish Hatchery during brood years (BY) 2000 - 2002. All fish were released at Lake Redding Park. Coded-wire tag (CWT) codes 0501030705, 051297, 051298, and 053737 were used for the progeny of captive broodstock held at the University of California-Davis Bodega Marine Laboratory. Average fork length (FL) is reported in millimeters and average weight in grams. Number released for each CWT is reported as (1) number released with an adipose fin clip (C) and CWT (T), (2) C and no CWT (NT), (3) No adipose fin clip (NC) and a T, and (4) NC and NT.

					Number Released			
BY	CWT Code	FL	Weight	Release Date	C/T	C/NT	NC/T	NC/NT
2000	0501030107	81	5.87	2/1/2001	8,023	124	83	41
2000	0501030108	82	6.01	2/1/2001	5,284	220	0	0
2000	0501030109	77	5.07	2/1/2001	5,550	172	0	0
2000	0501030201	72	4.08	2/1/2001	5,429	347	0	0
2000	0501030202	81	5.95	2/1/2001	5,241	395	0	0
2000	0501030203	81	5.80	2/1/2001	6,403	164	0	0
2000	0501030204	80	5.56	2/1/2001	5,586	203	0	0
2000	0501030205	82	6.02	2/1/2001	6,166	158	0	0
2000	0501030206	75	4.75	2/1/2001	6,901	70	0	0
2000	0501030207	78	5.28	2/1/2001	6,013	0	0	0
2000	0501030208	79	5.51	2/1/2001	5,381	54	0	0
2000	0501030209	77	5.10	2/1/2001	5,634	147	88	0
2000	0501030301	81	5.80	2/1/2001	5,500	56	0	0
2000	0501030302	79	5.34	2/1/2001	5,747	59	59	0
2000	0501030303	76	4.79	2/1/2001	5,966	91	0	0
2000	0501030304	77	5.16	2/1/2001	5,829	29	29	0
2000	0501030305	76	4.91	2/1/2001	5,333	27	0	0
2000	0501030306	83	6.31	2/1/2001	5,325	137	0	0
2000	0501030307	83	6.39	2/1/2001	5,007	102	0	0
2000	0501030308	72	4.13	2/1/2001	5,268	108	0	0

BY	CWT Code	FL	Weight	Release Date	Number Released			
					C/T	C/NT	NC/T	NC/NT
2000	0501030309	83	6.27	2/1/2001	4,798	48	0	0
2000	0501030401	80	5.61	2/1/2001	5,126	131	0	0
2000	0501030402	86	7.09	2/1/2001	4,826	98	0	0
2000	0501030403	84	6.45	2/1/2001	5,319	164	0	0
2000	0501030404	86	7.10	2/1/2001	4,439	161	0	0
2000	0501030405	84	6.56	2/1/2001	5,435	168	0	0
2000	0501030406	85	6.85	2/1/2001	4,763	73	0	0
2000	0501030407	81	5.82	2/1/2001	4,603	23	47	0
2000	0501030408	81	5.90	2/1/2001	4,666	23	0	0
2000	0501030409	87	7.30	2/1/2001	2,637	110	0	0
2001	0501020507	70	3.77	1/30/2002	4,263	0	0	21
2001	0501030705	75	4.65	1/30/2002	61,178	465	155	155
2001	0501030706	71	5.36	1/30/2002	37,465	697	387	155
2001	0501030707	85	6.84	1/30/2002	15,079	0	0	0
2001	0501030708	78	5.28	1/30/2002	6,053	673	0	0
2001	0501030709	77	5.11	1/30/2002	6,086	676	0	0
2001	0501030801	72	4.20	1/30/2002	5,009	103	52	0
2001	0501030802	80	5.66	1/30/2002	5,495	351	0	0
2001	0501030803	84	6.58	1/30/2002	4,882	424	0	0
2001	0501030804	78	5.33	1/30/2002	5,920	732	0	0
2001	0501030805	85	6.76	1/30/2002	4,705	146	0	0
2001	0501030806	77	5.27	1/30/2002	6,245	399	0	0
2001	0501030807	75	4.67	1/30/2002	4,499	139	0	0
2001	0501030808	73	4.26	1/30/2002	4,816	24	0	0
2001	0501030809	74	4.49	1/30/2002	5,194	216	0	0
2001	0501030901	78	5.26	1/30/2002	4,497	391	0	0

BY	CWT Code	FL	Weight	Release Date	Number Released			
					C/T	C/NT	NC/T	NC/NT
2001	0501030902	77	5.14	1/30/2002	4,673	325	0	0
2001	0501030903	77	4.98	1/30/2002	4,917	178	0	0
2001	0501030904	77	5.09	1/30/2002	5,339	253	28	0
2001	0501030905	76	4.90	1/30/2002	5,496	384	30	0
2001	0501030906	76	4.79	1/30/2002	5,156	362	56	0
2001	0501030907	76	4.85	1/30/2002	4,777	504	27	0
2001	0501030908	76	4.93	1/30/2002	5,731	573	32	32
2001	0501030909	75	4.72	1/30/2002	5,891	919	0	0
2001	0501040101	71	3.95	1/30/2002	4,610	23	0	0
2001	0501040102	73	4.28	1/30/2002	4,939	25	0	0
2001	0501040103	69	3.68	1/30/2002	4,676	48	96	0
2001	0501040104	69	3.62	1/30/2002	4,791	0	48	0
2002	051276	78	5.28	1/30/2003	3,756	116	0	0
2002	051277	71	4.41	1/30/2003	4,330	326	0	0
2002	051278	73	4.68	1/30/2003	4,429	137	0	0
2002	051279	73	4.54	1/30/2003	3,762	262	0	0
2002	051280	72	4.37	1/30/2003	4,224	176	0	0
2002	051281	80	5.59	1/30/2003	4,318	111	22	0
2002	051282	82	6.55	1/30/2003	5,626	525	31	0
2002	051283	79	6.77	1/30/2003	5,350	840	31	0
2002	051284	80	6.46	1/30/2003	5,410	535	0	0
2002	051285	86	7.83	1/30/2003	4,143	435	0	0
2002	051286	83	6.24	1/30/2003	5,005	128	0	0
2002	051287	79	6.37	1/30/2003	3,405	601	0	0
2002	051288	78	5.31	1/30/2003	4,992	555	0	0
2002	051289	78	4.98	1/30/2003	5,831	243	0	0

BY	CWT Code	FL	Weight	Release Date	Number Released			
					C/T	C/NT	NC/T	NC/NT
2002	051290	82	8.22	1/30/2003	8,086	804	45	0
2002	051291	74	4.69	1/30/2003	5,680	146	0	0
2002	051292	74	4.70	1/30/2003	4,377	230	0	0
2002	051293	74	4.43	1/30/2003	4,425	234	23	0
2002	051294	75	4.78	1/30/2003	4,489	212	0	0
2002	051295	91	8.46	1/30/2003	2,294	358	0	0
2002	051296	80	7.14	1/30/2003	10,425	549	0	0
2002	051297	72	5.09	1/30/2003	17,364	1,207	0	0
2002	051298	64	3.59	1/30/2003	26,472	274	686	0
2002	051299	83	6.62	1/30/2003	4,341	66	0	0
2002	051364	79	5.50	1/30/2003	4,778	502	0	0
2002	051365	79	5.12	1/30/2003	4,235	368	0	0
2002	051366	79	5.19	1/30/2003	4,403	136	0	0
2002	051367	82	6.09	1/30/2003	4,671	144	0	0
2002	051368	78	5.22	1/30/2003	4,451	68	0	0
2002	051369	75	5.03	1/30/2003	4,556	165	0	0
2002	051370	78	5.16	1/30/2003	4,621	24	71	0
2002	051371	72	4.81	1/30/2003	5,329	283	57	0
2002	051372	73	4.34	1/30/2003	4,948	102	25	0
2002	051373	77	5.16	1/30/2003	4,230	199	0	0
2002	053737	65	3.16	1/30/2003	22,576	228	0	0

Appendix D. Genetic results of fin tissues collected from Chinook salmon carcasses during the 2004 upper Sacramento River winter Chinook salmon carcass survey. Data presented includes sample collection date, sample number assigned by the Service, LOD score determined by the Abernathy Fish Technology Center, run assignment (LOD > 2 for winter), gender observed during the 2004 winter Chinook carcass survey (Phenotype), and gender determined through genetic analysis of the growth hormone pseudogene marker (Genotype).

				Gender	
Date	Sample #	LOD	Strain	Phenotype	Genotype
4/30/2004	04-25001	5.9484	Winter	Female	Female
5/1/2004	04-25002	2.5892	Winter	Male	Male
5/1/2004	04-25003	-5.6629	Non-Winter	Female	Female
5/3/2004	04-25004	-7.0879	Non-Winter	Female	Female
5/4/2004	04-25005	-4.1962	Non-Winter	Female	Female
5/9/2004	04-25006	failed		Male	Female
5/10/2004	04-25007	-4.1887	Non-Winter	Female	Female
5/10/2004	04-25008	-6.3405	Non-Winter	Female	Female
5/10/2004	04-25009	6.0091	Winter	Female	Female
5/12/2004	04-25010	4.0259	Winter	Male	Male
5/16/2004	04-25011	2.7991	Winter	Female	Female
5/18/2004	04-25012	-6.9460	Non-Winter	Female	Female
5/19/2004	04-25013	7.0261	Winter	Male	Male
5/22/2004	04-25014	7.8189	Winter	Male	Male
5/22/2004	04-25015	failed		Male	Female
5/22/2004	04-25016	-7.7465	Non-Winter	Female	Female
5/22/2004	04-25017	-8.7733	Non-Winter	Male	Male
5/24/2004	04-25018	5.9113	Winter	Male	Female
5/24/2004	04-25019	4.6992	Winter	Female	Female
5/24/2004	04-25020	4.6246	Winter	Female	Female
5/27/2004	04-25022	5.0178	Winter	Male	Male
5/27/2004	04-25023	6.4164	Winter	Female	Female
5/28/2004	04-25024	4.4883	Winter	Male	Male
5/28/2004	04-25025	-5.7000	Non-Winter	Female	Female
5/28/2004	04-25026	2.5169	Winter	Male	Male
5/30/2004	04-25027	3.5951	Winter	Female	Female
5/31/2004	04-25028	-6.3451	Non-Winter	Female	Female
5/31/2004	04-25029	7.2168	Winter	Female	Female
6/3/2004	04-25032	7.1427	Winter	Female	Female
6/3/2004	04-25034	5.5512	Winter	Female	Female
6/5/2004	04-25044	failed		Female	Female
6/6/2004	04-25048	4.5090	Winter	Female	Female
6/9/2004	04-25055	2.2746	Winter	Male	Female

				Gender	
Date	Sample #	LOD	Strain	Phenotype	Genotype
6/11/2004	04-25062	2.5240	Winter	Female	Female
6/12/2004	04-25065	3.7478	Winter	Female	Female
6/14/2004	04-25076	-0.8949	Non-Winter	Female	Female
6/15/2004	04-25084	8.6590	Winter	Male	Male
6/15/2004	04-25085	1.5925	Non-Winter	Male	Male
6/17/2004	04-25090	3.0091	Winter	Female	Female
6/18/2004	04-25100	3.8088	Winter	Female	Female
6/18/2004	04-25106	failed		Female	Female
6/19/2004	04-25110	3.3874	Winter	Male	Female
6/20/2004	04-25116	9.0572	Winter	Female	Female
6/20/2004	04-25121	3.3847	Winter	Female	Female
6/21/2004	04-25129	1.0725	Non-Winter	Female	Female
6/21/2004	04-25132	8.5124	Winter	Male	Male
6/21/2004	04-25135	9.1760	Winter	Male	Male
6/22/2004	04-25142	4.0008	Winter	Male	Male
6/23/2004	04-25147	4.7257	Winter	Male	Male
6/23/2004	04-25157	7.3055	Winter	Male	Male
6/23/2004	04-25162	10.0217	Winter	Male	Male
6/25/2004	04-25176	7.7241	Winter	Male	Male
6/26/2004	04-25179	6.0197	Winter	Male	Male
6/27/2004	04-25197	5.5103	Winter	Female	Female
6/28/2004	04-25205	3.9320	Winter	Male	Male
6/29/2004	04-25211	3.4525	Winter	Male	Male
6/30/2004	04-25219	1.8546	Non-Winter	Male	Male
6/30/2004	04-25224	5.1505	Winter	Female	Female
7/2/2004	04-25239	8.5568	Winter	Female	Female
7/2/2004	04-25240	5.0982	Winter	Female	Female
7/3/2004	04-25249	4.3722	Winter	Male	Male
7/3/2004	04-25252	6.0429	Winter	Female	Female
7/1/2004	04-25259	7.8921	Winter	Female	Female
7/5/2004	04-25269	6.2062	Winter	Female	Female
7/8/2004	04-25296	5.2022	Winter	Female	Male
7/8/2004	04-25297	7.5779	Winter	Female	Male
7/9/2004	04-25311	4.3401	Winter	Female	Female
7/12/2004	04-25338	4.1241	Winter	Female	Female
7/12/2004	04-25343	0.7087	Non-Winter	Male	Female
7/14/2004	04-25375	5.4514	Winter	Female	Female
7/18/2004	04-25401	2.7657	Winter	Female	Female
7/18/2004	04-25403	4.7117	Winter	Female	Female
7/20/2004	04-25422	4.3956	Winter	Male	Male

				Gender	
Date	Sample #	LOD	Strain	Phenotype	Genotype
7/21/2004	04-25439	5.8230	Winter	Female	Male
7/23/2004	04-25443	8.5665	Winter	Female	Female
7/26/2004	04-25460	2.9411	Winter	Female	Female
7/30/2004	04-25481	-0.0789	Non-Winter	Female	Female
8/1/2004	04-25487	1.3277	Non-Winter	Female	Female
8/2/2004	04-25488	9.8770	Winter	Female	Male
8/2/2004	04-25489	2.4523	Winter	Female	Female
8/2/2004	04-25490	8.0457	Winter	Female	Female
8/2/2004	04-25491	3.2941	Winter	Female	Male
8/2/2004	04-25493	9.2848	Winter	Female	Female
8/2/2004	04-25494	6.9205	Winter	Female	Female
8/2/2004	04-25499	9.7637	Winter	Female	Female
8/2/2004	04-25500	9.7702	Winter	Female	Female
8/4/2004	04-25501	8.0571	Winter	Female	Female
8/5/2004	04-25503	3.7795	Winter	Female	Female
8/5/2004	04-25504	5.3927	Winter	Female	Female
8/5/2004	04-25505	3.1113	Winter	Female	Female
8/5/2004	04-25506	9.2997	Winter	Female	Female
8/5/2004	04-25507	5.5949	Winter	Female	Female
8/5/2004	04-25508	3.9660	Winter	Female	Female
8/5/2004	04-25510	2.5856	Winter	Female	Female
8/5/2004	04-25511	4.3165	Winter	Female	Female
8/7/2004	04-25513	7.0778	Winter	Female	Female
8/7/2004	04-25514	5.3423	Winter	Female	Female
8/11/2004	04-25519	3.9546	Winter	Female	Female
8/13/2004	04-25520	-12.1643	Non-Winter	Female	Female
8/14/2004	04-25521	0.1138	Non-Winter	Female	Female
8/14/2004	04-25522	3.7705	Winter	Female	Female
8/20/2004	04-25523	6.5055	Winter	Female	Female
4/5/2004	04-26001	failed		Male	Female
4/13/2004	04-26002	-4.6589	Non-Winter	Female	Female
4/12/2004	04-26003	-5.4357	Non-Winter	Female	Female
4/5/2004	04-26004	-7.1529	Non-Winter	Male	Female
4/12/2004	04-26005	-7.9851	Non-Winter	Male	Male
4/5/2004	04-26006	-3.2046	Non-Winter	Female	Female
4/19/2004	04-26007	-9.5770	Non-Winter	Male	Male
4/26/2004	04-26008	-4.3406	Non-Winter	Female	Female
4/26/2004	04-26009	7.2099	Winter	Male	Female
4/26/2004	04-26010	-4.5297	Non-Winter	Female	Female
4/26/2004	04-26011	3.8730	Winter	Female	Female

				Gender	
Date	Sample #	LOD	Strain	Phenotype	Genotype
5/1/2004	04-45502	-3.2124	Non-Winter	Female	Female
5/3/2004	04-45503	3.1863	Winter	Female	Female
5/3/2004	04-45504	-7.4231	Non-Winter	Female	Female
5/3/2004	04-45505	-1.1761	Non-Winter	Male	Male
5/4/2004	04-45506	9.5647	Winter	Male	Male
5/10/2004	04-45507	2.7673	Winter	Male	Male
5/12/2004	04-45508	7.2253	Winter	Female	Female
5/22/2004	04-45510	4.8137	Winter	Female	Female
5/24/2004	04-45511	-9.7760	Non-Winter	Female	Female
5/25/2004	04-45512	3.8324	Winter	Female	Female
5/25/2004	04-45513	1.4886	Non-Winter	Male	Male
5/27/2004	04-45514	4.5550	Winter	Male	Female
5/27/2004	04-45515	7.5882	Winter	Male	Male
5/27/2004	04-45516	7.4630	Winter	Male	Female
5/28/2004	04-45517	4.5867	Winter	Male	Male
5/28/2004	04-45518	-5.0891	Non-Winter	Male	Female
5/30/2004	04-45519	7.8190	Winter	Female	Female
5/30/2004	04-45520	4.0870	Winter	Male	Male
5/31/2004	04-45521	-9.7760	Non-Winter	Male	Female
5/31/2004	04-45522	4.4486	Winter	Female	Female
5/31/2004	04-45523	2.8989	Winter	Female	Female
6/14/2004	04-45546	5.2774	Winter	Female	Female
6/18/2004	04-45565	5.7497	Winter	Male	Male
6/24/2004	04-45607	8.1352	Winter	Male	Female
6/24/2004	04-45609	4.2982	Winter	Female	Female
6/26/2004	04-45619	5.3914	Winter	Female	Female
6/29/2004	04-45630	7.6050	Winter	Male	Male
7/5/2004	04-45660	7.7995	Winter	Female	Female
7/5/2004	04-45663	6.1226	Winter	Male	Female
7/6/2004	04-45672	9.9575	Winter	Female	Female
7/9/2004	04-45692	4.2603	Winter	Female	Female
7/11/2004	04-45700	5.1446	Winter	Female	Female
7/11/2004	04-45707	failed		Female	Female
7/12/2004	04-45720	4.6256	Winter	Female	Female
7/14/2004	04-45724	2.5687	Winter	Female	Female
7/15/2004	04-45729	5.8671	Winter	Female	Female
7/15/2004	04-45737	8.7439	Winter	Female	Female
7/16/2004	04-45745	4.9446	Winter	Male	Female
7/17/2004	04-45746	8.4858	Winter	Male	Male
7/24/2004	04-45796	4.9862	Winter	Female	Female

				Gender	
Date	Sample #	LOD	Strain	Phenotype	Genotype
7/24/2004	04-45797	7.8358	Winter	Female	Female
7/26/2004	04-45800	3.0204	Winter	Male	Female
7/29/2004	04-45815	9.3332	Winter	Male	Male
8/1/2004	04-45823	1.8564	Non-Winter	Female	Female
8/1/2004	04-45824	3.8151	Winter	Female	Female
8/2/2004	04-45827	6.1463	Winter	Female	Female
8/2/2004	04-45828	4.2044	Winter	Female	Female
8/2/2004	04-45829	4.6073	Winter	Female	Female
8/2/2004	04-45830	0.6515	Non-Winter	Female	Female
8/2/2004	04-45831	6.9771	Winter	Female	Female
8/2/2004	04-45833	5.3686	Winter	Female	Female
8/2/2004	04-45834	6.8183	Winter	Female	Female
8/2/2004	04-45835	6.3230	Winter	Female	Female
8/2/2004	04-45836	7.3536	Winter	Female	Female
8/2/2004	04-45838	5.9271	Winter	Female	Female
8/5/2004	04-45840	7.5318	Winter	Female	Female
8/2/2004	04-45841	10.0756	Winter	Female	Female
8/5/2004	04-45842	4.8712	Winter	Female	Female
8/5/2004	04-45843	1.8354	Non-Winter	Female	Female
8/8/2004	04-45844	7.8443	Winter	Female	Female
8/8/2004	04-45845	1.5494	Non-Winter	Female	Female
8/14/2004	04-45846	4.1123	Winter	Female	Female
8/14/2004	04-45847	7.1445	Winter	Female	Female
8/14/2004	04-45848	4.4652	Winter	Female	Female
8/14/2004	04-45849	3.7540	Winter	Female	Female